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APOLLO PHOTOGRAPH EVALUATION (APE)

PROGRAMMING MANUAL

NAS 9-12330

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Prepared by

I. J. Kim
Analysis and Experiment Support Section
TRW Systems Group

Prepared for
Mission Planning and Analysis Division
National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas

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Prepared by I. J. Kim
I. J. Kim
Analysis and Experiment
Support Section

Approved by E. D. Stuckle
E. D. Stuckle, Manager
Software Technology
Applications Department

Approved by J. B. Moore
J. B. Moore, Manager
JSC/TRW Task AA-53

Approved by E. L. Barnett
E. L. Barnett
Assistant Project Manager
Mission Trajectory Control
Program

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ABSTRACT

This report is submitted to NASA/JSC by TRW Systems Group in accordance with JSC/TRW Task AA-53 of the Mission Trajectory Control Program, Contract NAS 9-12330.

This document describes the programming techniques used to implement the equations of the Apollo Photograph Evaluation (APE) Program on the UNIVAC 1108 computer and contains detailed descriptions of the program structure, a User's Guide section to provide the necessary information for proper operation of the program, and information for the assessment of the program's adaptability to future problems.

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1. INTRODUCTION

APOLLO PHOTOGRAPH EVALUATION (APE) PROGRAMMING MANUAL

Prepared by:

I. J. Kim

Analysis and Experiment Support Section
TRW Systems Group

1. INTRODUCTION

This programming manual presents the information necessary for the use and assessment of the Apollo Photograph Evaluation (APE) computer program in its final form (Version 9). The description of an earlier version, which is restricted in application to lunar orbiter photograph evaluation data generation, can be found in Reference 1.

APE is a moon-centered, mixed precision, UNIVAC 1108 computer program designed and constructed for the generation of initial postflight estimates of location, orientation, and lighting of photographs taken with Apollo CSM-mounted cameras. The program, developed by TRW Systems Group for the Johnson Space Center at Houston, Texas, is written in FORTRAN V for use on the EXEC II system.

The general applications of APE are discussed in Section 2.1. The special applications of APE for the prediction of stellar camera star patterns and for the production of data in support of certain nonphotographic Apollo experiments are discussed in Section 2.2. Section 3 presents a detailed description of the program structure. Section 4 provides all the information required for proper use of the program. Descriptions of APE special application alter decks are presented in the Appendix.

2. PROGRAM DESCRIPTION

2. PROGRAM DESCRIPTION

2.1 GENERAL APPLICATION

The general application of APE is to generate support data for the evaluation of photographic data from any of the following Apollo CSM cameras: sextant, SIM-bay mapping, SIM-bay panoramic, and window mounted. For this application, APE produces a standard output tape and an on-line printout of the photograph evaluation parameters listed in Table 2-1. The format of the standard APE output tape is presented in Table 4-15. The on-line output is assigned to FORTRAN unit 6, while the tape output is assigned to FORTRAN unit 4.

Table 2-1. Photographic Evaluation Parameters - General Application

Output Parameter	Description
Title and page	Title and page (or photo frame) number.
GMT	Sidereal time of film exposure (year, month, day, hour, minute, second) - (UT1 - USNO).
CTE	Central clock time of film exposure which is recorded on the film (hour, minute, second).
1950 state vector	Mean of 1950 moon centered, inertial, cartesian coordinates of the spacecraft position (km) and velocity (km/sec).
Selenographic state vector	Selenographic, instantaneous inertial cartesian coordinates of vehicle position (km) and velocity (km/sec).
Nadir point (longitude/latitude)	Intersection with the mean lunar surface of the vector from the moon's center of mass to the spacecraft.
Camera axis intersect (longitude/latitude)	Position of principal intersection point; intersection of camera optical axis direction with mean lunar surface.
Spacecraft radius	Vector from moon center of mass to spacecraft.
Spacecraft altitude	Height of spacecraft above mean lunar surface.

Table 2-1. Photographic Evaluation Parameters - General Application (Continued)

Output Parameter	Description
Scale factor	Proportionality constant relating dimensions on the film to dimensions on the mean lunar surface.
Azimuth of velocity vector	Angle, measured positive clockwise in the local horizontal plane at nadir, between north and the projection of the vehicle velocity vector onto the local horizontal plane.
Mean altitude rate	Rate of change in spacecraft altitude above the mean lunar surface.
Horizontal velocity	Component of spacecraft velocity parallel to the lunar local horizontal plane at the nadir point.
Tilt azimuth	Angle, measured positive clockwise in the local horizontal plane at the principal intersection point, between north and the projection of a vector along the camera optical axis onto that local horizontal plane.
Tilt	Angle between the camera optical axis direction and the lunar local vertical at the nadir point.
Sun elevation at principal ground point	Angle between the vector from the sun to the principal intersection point and the lunar local horizontal plane at the point.
Sun azimuth at principal ground point	Angle, measured positive clockwise in the lunar local horizontal plane, from north to the projection of the vector from the sun to the principal intersection point onto that plane.
Subsolar point (longitude/latitude)	Intersection with the mean lunar surface of a vector from the moon's center of mass to the sun's center.
Alpha	Angle between the camera optical axis and the projection of the lunar local vertical at the principal intersection point onto the plane of the phase angle (measure of surface tilt toward or away from the sun).

Table 2-1. Photographic Evaluation Parameters - General Application (Continued)

Output Parameter	Description
Swing	Angle between the camera Y-axis and the projection of the line between the vehicle nadir and principal intersection point onto the camera X-Y plane.
Emission angle	Angle between the camera optical axis and the lunar local vertical at the principal intersection point.
Phase angle	Angle between the camera optical axis and the vector from the sun to the principal intersection point.
North deviation angle	Angle, measured positive clockwise in the camera X-Y plane, from the camera X-axis to lunar north.
Phi, Kappa, Omega	Angles which rotate the camera axes coordinate system into the nadir point centered lunar local horizontal system, where: - Primary right-handed rotation about the camera Y-axis - Secondary right-handed rotation about the intermediate X-axis - Final right-handed rotation about the local vertical (local horizontal Z-axis)
X-tilt	(lateral tilt) Angle from the local horizontal plane at the nadir point to the camera Y-axis.
Y-tilt	(longitudinal tilt) Angle from the local horizontal plane at the nadir point to the camera X-axis.
Heading	Angle, measured positive clockwise in the lunar hoirzontal plane at the nadir point, from north to the projection of the camera X-axis onto that plane.
Laser slant range	Telemetered laser altimeter readout.
Spacecraft altitude (laser)	Vertical component of laser altimeter slant range based on the assumption that the laser altimeter was aligned along the three-inch mapping camera optical axis.

Table 2-1. Photographic Evaluation Parameters - General Applications (Continued)

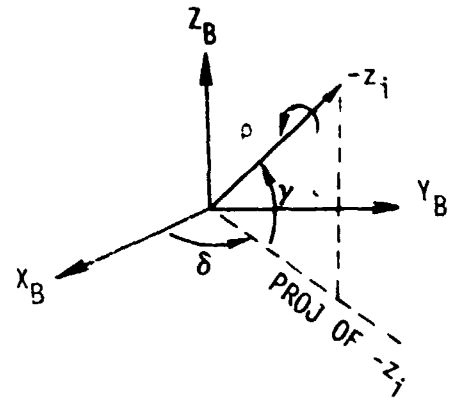
Output Parameter	Description
Selenographic direction cosines	Direction definition of vector from the spacecraft to the principal intersection point in the instantaneous inertial selenographic coordinate system.
Coordinate transformation matrices	Selenocentric coordinate system to camera axes coordinate system and local horizontal coordinate system to the camera axes coordinate system.
Photograph footprint	Latitudes and longitudes of field of view corner point projections onto the lunar surface (full field of view only for mapping camera, full field of view and inner field of view for panoramic camera).
Sigmas	First order uncertainties in selected camera aiming parameters arising from uncertainties in camera mounting angles, vehicle attitude measurements and film exposure times.

2.1.1 Generalized Fixed Camera

This model, developed for consideration of any of the early Apollo window-mounted cameras, is the basic APE camera model. This simple, three-degree-of-freedom camera model, with the camera axes oriented as shown in Figure 2-1, provides the program logic for essentially all APE geometric definitions. This same basic logic is used for the APE definition of instrument-vehicle-target geometry, and all of its applications after the instrument mounting and control parameters are converted to generalized APE instrument mounting angle equivalents for definition of the spacecraft body axes to instrument axes transformation. This redefinition is by way of the following coordinate transformation matrix:

$$[BD2CM] = \begin{bmatrix} \cos\rho & \sin\rho & 0 \\ -\sin\rho & \cos\rho & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \sin\gamma & 0 & \cos\gamma \\ 0 & 1 & 0 \\ -\cos\gamma & 0 & \sin\gamma \end{bmatrix} \begin{bmatrix} \cos\delta & \sin\delta & 0 \\ -\sin\delta & \cos\delta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (1)$$

where: ρ (RHO), γ (DOQ) and δ (DOR) are the generalized APE camera or instrument mounting angles.



ρ, γ and δ = camera mounting angles

Figure 2-1. Generalized Camera Axes Coordinate System

Regardless of the camera or instrument under consideration by APE, the above transformation matrix is applied after the parameters of that matrix have been properly defined in terms of the mounting and control angles of the specific instrument or camera being considered. These definitions are according to the following formulae which arise from equating the vehicle axes to instrument axes coordinate transformation [M] to the above [BD2CM]:

$$\rho = \tan^{-1}\left(\frac{-M_{23}}{M_{13}}\right)$$

$$\gamma = \sin^{-1} M_{33} = \tan^{-1}\left(\frac{\cos\rho \; M_{33}}{M_{13}}\right)$$

$$\delta = \tan^{-1}\left(\frac{-M_{32}}{-M_{31}}\right)$$

Generally speaking, the treatment of any instrument, other than a simple fixed mounted camera without precise shutter timing definition, requires additional logic to reflect special features and requirements.

The additions required for consideration of the various Apollo cameras and instruments are discussed in the following sections devoted to those particular cameras and instruments.

2.1.2 Sextant Camera (ISHFTR = 2)

The Apollo sextant camera, used only on Apollo 12 and Apollo 14, differs from all other Apollo cameras in that it has time varying sextant shaft angle (β') and sextant trunnion angle (θ'). The processing of data from this camera by APE requires either that histories of these angles be input by tape or that their values at all computation times be input on cards (Input 2). When input by tape, these histories are included with the CSM attitude data (pre-Apollo 15 gimbal tape format (Table 4-12)).

When operating on sextant camera data, APE first converts the camera mounting angles γ', β', θ' (Table 2-2), whose values are either provided by card input or are interpolated from tape input histories, to the equivalent general camera mounting angles ρ, γ, δ by way of conversion formulae. These equivalents are then employed in the construction of the BD2CM matrix for use in the nominal program flow (Figure 2-2).

Table 2-2. Card Input Sextant Mounting Angles

Namelist Input (degrees)	Internal Variable (radians)
β' : Sextant shaft angle = CSHAFT (real)	SXSHFT
θ' : Sextant trunnion angle = CTRUN (real)	SXTRUN
γ' : Constant position angle = SXLAMB (double precision)	DOP

Referring to Figure 2-2, the transformation (BD2CAM) is defined as follows:

$$[BD2CM] = \begin{bmatrix} -\cos\theta' & 0 & \sin\theta' \\ 0 & 1 & 0 \\ -\sin\theta' & 0 & -\cos\theta' \end{bmatrix} \begin{bmatrix} \cos\beta' & \sin\beta' & 0 \\ -\sin\beta' & \cos\beta' & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\gamma' & 0 & -\sin\gamma' \\ 0 & 1 & 0 \\ \sin\gamma' & 0 & \cos\gamma' \end{bmatrix} \quad (2)$$

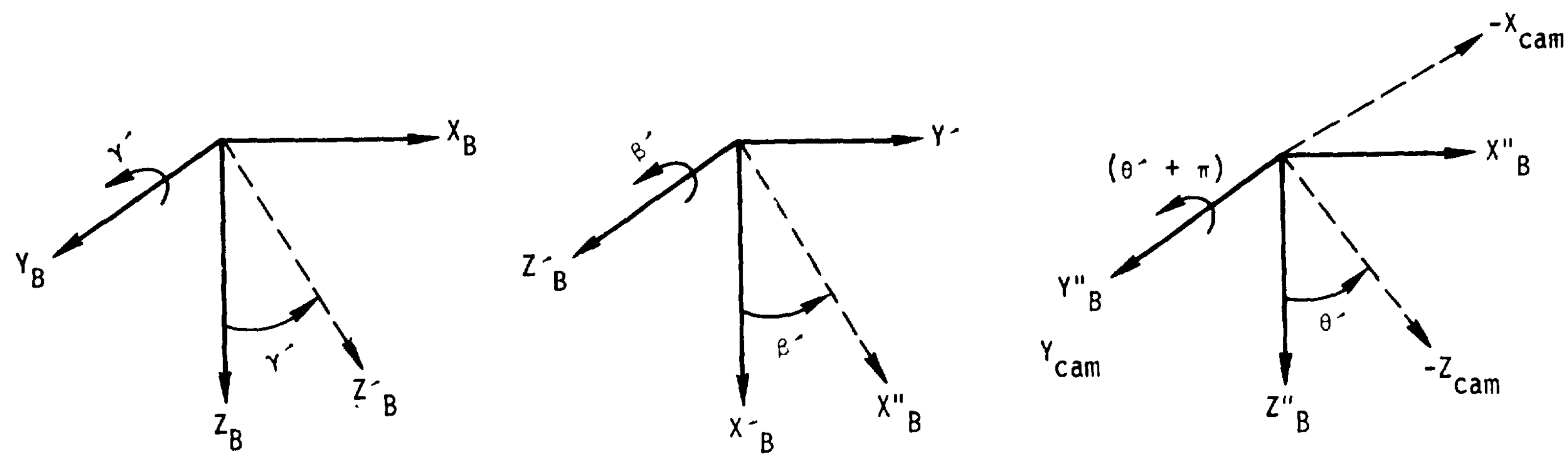
In the program, the elements of BD2CM are computed by equation 1 using the converted ρ, γ, and δ (equation 3).

$$\left.\begin{aligned}
\rho &= \tan^{-1}\left(\frac{-\sin\beta}{\cos\theta \quad \cos\beta' + \sin\theta' \quad \cot\gamma'}\right) \\
\gamma &= \sin^{-1}\left(\sin\theta' \quad \cos\beta' \quad \sin\gamma' - \cos\theta' \quad \cos\gamma'\right) \\
\delta &= \tan^{-1}\left(\frac{\sin\beta'}{\cos\beta' \quad \cos\gamma' + \sin\gamma' \quad \cot\gamma'}\right)
\end{aligned}\right\} \qquad (3)$$

Primary - γ' rotation about $Y_{Body\text{-}axis}$

Secondary - β' rotation about $Z'_{Body\text{-}axis}$

Tertiary - $(\theta' + \pi)$ rotation about $Y''_{Body\text{-}axis}$



where

γ' = Constant Position Angle

where

β' = Shaft Angle

where

θ' = Trunnion Angle

Figure 2-2. Sextant Mounting Angles

2.1.3 SIM-Bay Mapping Camera

The SIM-bay mapping camera was used on Apollo flights 15, 16, and 17 and synchronized with the Apollo stellar camera and laser altimeter. The APE treatment of this camera requires a card input of photo frame number, onboard clock film exposure time and where available, laser altimeter slant range for each computational point. These cards, in the format shown in Table 4-5, are input as a chronologically ordered card deck which follows the control card input ($INPUT1). The input deck must be ordered, in position and number, to exactly match the vectors appearing on the input trajectory tape. A card containing an X in column 5 must be included in this deck in the position which corresponds to every vector appearing on the input trajectory tape which does not correspond to a film exposure time.

This application also requires that appropriate values for the mapping camera to stellar camera interlock angles θ_X, θ_Y, and θ_Z be set by a data statement at sequence number 178 of subroutine APECOM as I1, I2, and I3, respectively. These angles must be input in radians.

The mapping camera optical axis (-Z cam) lies along the SIM-bay centerline which is inclined 37.75° to the Z-body axis as shown in Figure 2-3.

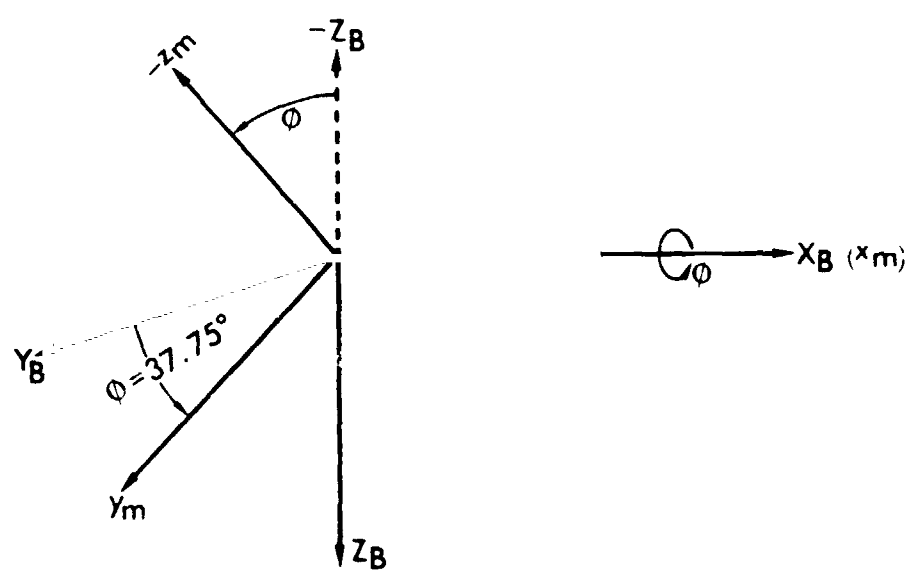


Figure 2-3. SIM-Bay 3-Inch Mapping Camera Axes Coordinate System

The APE program first converts the camera mounting to the APE generalized camera mounting parameters ρ (RHO), γ (DOQ), and δ (DOR) as follows:

$$\rho = \frac{3\pi}{2}, \qquad \gamma = \frac{\pi}{2} - \phi, \qquad \delta = \frac{\pi}{2}$$

where: ϕ = Mapping camera mounting angle (37.75°)

The mapping camera computations are then carried out by way of the nominal APE flow modified to:

1. Transport photo frame number, onboard clock film exposure time and laser altimeter slant range from card to output
2. Compute vertical component of laser altimeter slant range for output
3. Compute right ascension and declination of stellar camera aiming axis for output

The APE outputs for this camera are unique in that they include, in addition to the standard set of parameters, laser altitude, laser slant range, and stellar camera aiming direction (right ascension and declination).

2.1.4 Apollo Panoramic Camera (ISHFTR = 4)

The Apollo panoramic camera was used on Apollo flights 15, 16, and 17. This camera has two operational modes: "stereo" and "mono." In the "stereo" mode, the camera oscillated between +12.5° forward and -12.5° aft of the SIM-bay center line (Figure 2-4) at a nominal frequency of 10 cpm but which was varied according to altitude range. In the "mono" mode the panoramic camera was held in a fixed position with its optical axis directed along the SIM-bay center line in a position identical with the mapping camera (Figure 2-3). The APE treatment of this camera requires a card input of photo frame number and onboard clock time of film exposure for each computational point. These cards, in the format shown in Table 4-6 are input as a chronologically ordered card deck which follows the control card input (RINPUT1). The deck must be ordered to exactly match, in position and number, the vectors appearing on the input trajectory tape. A card containing an X in column 2 must be included in this card deck in the position corresponding to every vector appearing on the input trajectory tape which does not correspond to a film exposure time.

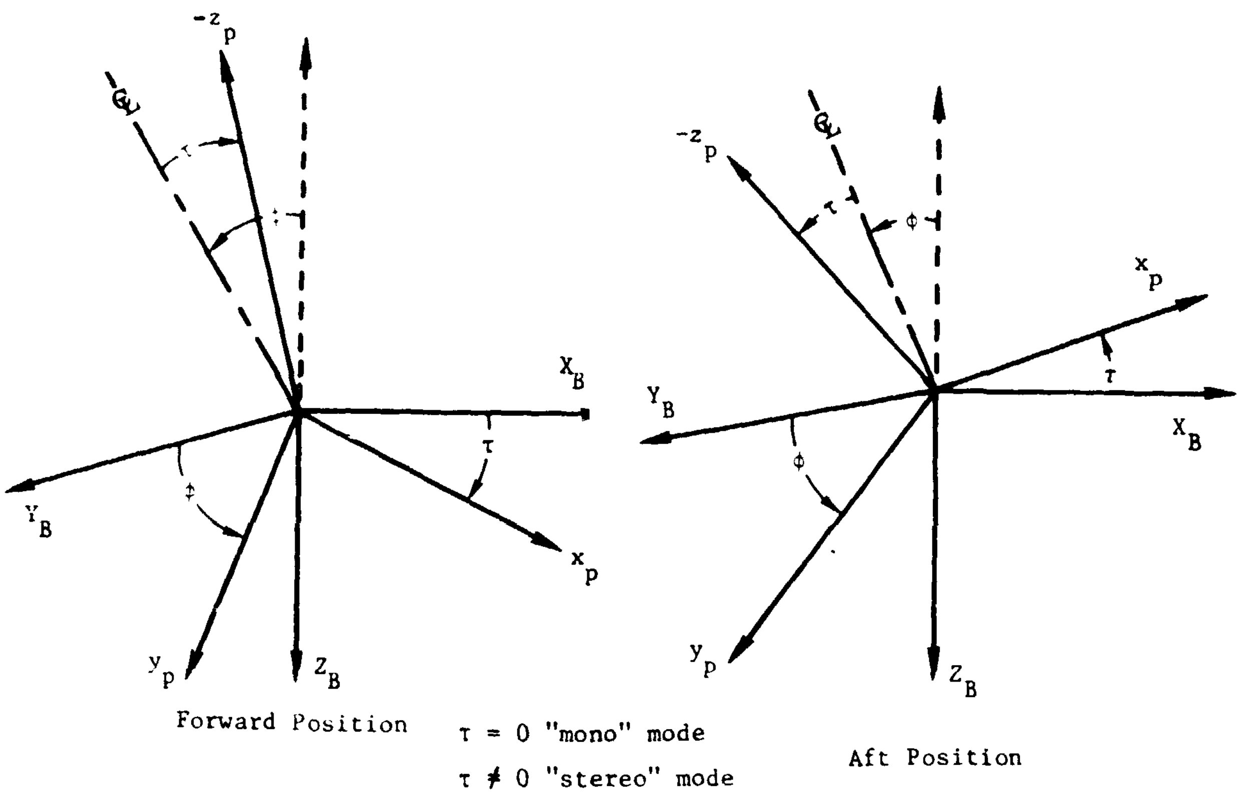


Figure 2-4. Panoramic Camera Axes Coordinate System

The first character of the card input photo frame number designates camera mode and camera aiming direction. This designation, the input for the APE parameter KOPAN, determines the computational flow. If the designator is V, then the "mono" mode flow is followed; otherwise, the "stereo" mode flow is followed.

When in the "mono" mode (KOPAN = V), the computational flow is that of the SIM-bay mapping camera (ISHFTR = 2) modified to omit the computations of vertical component of laser altimeter slant range and of the stellar camera aiming direction.

When in the "stereo" mode (KOPAN = A or F), APE first converts the panoramic camera mounting angles ϕ = 37.75 (mounting angle) and τ (excursion angle) to the equivalent generalized APE camera mounting angles ρ (RHO), γ (DOQ) and δ (DOR) as follows:

$$\rho = \tan^{-1}\left[\frac{-\sin\phi}{-\sin\ (K\tau)\ \cos\phi}\right]$$

$$\gamma = \sin^{-1}\left[\cos\ (K\tau)\ \cos\phi\right]$$

$$\delta = \tan^{-1}\left[\frac{\cos\ (K\tau)\ \sin\phi}{-\sin\ (K\tau)}\right]$$

where: ϕ = 37.75° (nominal)

τ = 12.5° (nominal)

K = Switching constant

= -1 when KOPAN = F

= +1 when KOPAN = A

The outputs for this camera are unique in that they include an additional set of field of view corner point locations (inner field of view). Stellar camera aiming axis right ascension and declination and laser altimeter and slant range are omitted from the output.

See Appendix A.1 for a description of the alters required for the operation of this program option.

2.2 SPECIAL APPLICATIONS

Special applications of the APE program will produce predictions of star patterns within the Apollo stellar camera field of view at specified film exposure times or support data for the Apollo IR scanner and lunar sounder experiments. These applications all deviate from the generalized APE applications in some combination of input, computational, or output requirements.

2.2.1 Apollo Stellar Camera (ISHFTR = 3)

This special application of APE locates and computes the diapositive coordinates of the brightest BOSS numbered star in each of 16 equal sectors of the Apollo stellar camera field of view at specified film exposures times. This, a time consuming application, was used to establish one or two star patterns for each Apollo stellar camera photographic sequence.

For this application, APE first defines the generalized APE camera mounting angles ρ, γ, and δ in terms of the SIM-bay mapping camera mounting angle (ϕ) and the map to stellar camera interlock angles θ_X, θ_Y, and θ_Z. These interlock angles are input to APE by way of a data statement at sequence number 178 of subroutine APECOM, where these angles are defined in radians as I1, I2, and I3, respectively. Following this definition of ρ, γ, and δ, the APE computational flow is identical with that for the SIM-bay mapping camera through the definition of the stellar camera aiming axis direction. At that point the calculations deviate to a program overlay for access to the star catalog search subroutine STARRD. The overlayed program structure is used to access a maximum amount of core for the bi-level star catalog search to increase the computational speed.

In the first level of the STARRD star catalog search, APE transfers all stars within APE computed ranges of mean of 1950 right ascension and declination from the input Apollo photo evaluation star catalog tape to computer core. In its second level of the STARRD search, APE selects from its stored stars the brightest one in each of 16 equal sectors of the stellar camera field of view at film exposure time. These are then on-line plotted, using APE computed stellar camera diapositive coordinates. This plot is followed in the output by a tabulation of the plotted stars; the star identification (SAO and BOSS number), the star diapositive coordinates, and brightness.

This application requires the input of an additional tape on unit X which is the Apollo Photograph Evaluation (APE) star catalog. This catalog, an extraction from the June 1967 SAO star catalog binary tapes, was prepared by TRW Systems Group and contains data only for those stars which have a photographic brightness of six or brighter and which have been assigned a BOSS catalog number. The data for each star, presented in the format described in Table 4-14, include SAO and BOSS catalog identification numbers, along with selected parameters that enter the APE computations.

Depending on the composition and arrangement of the APE input deck, star pattern predictions for any number of film exposures for a given Apollo stellar camera photographic sequence can be obtained, either isolated from or in conjunction with, the APE processing of the companion SIM-bay mapping camera data, with a single multi-execution of the program. The input deck must contain, for each star pattern requested, a complete $INPUT1, stellar camera card deck, preceded by a title card and followed by the map camera data card corresponding to the film exposure of the request and then by another title card. Each of these $INPUT1 decks must contain the following inputs:

ISHFTR = 3
ISSEQI = Corresponding map camera photograph number
ISSEQF = Number beyond final photograph of the sequence
ISHFT = -5 (all except for the final case)

When the APE application is for a series of star pattern predictions, the required $INPUT1 card decks must be chronologically ordered with no overlap of the intervals defined by the input star and stop times. Processing of the companion SIM-bay mapping camera data can be accomplished in the same multi-execution of APE by including its $INPUT1 card deck as the final input deck.

2.2.2 Infrared Scanning Radiometer (S-171)

This special APE application produces support data for the Apollo infrared scanning radiometer experiment used during Apollo 17 flight. For this special application of APE, no additional card inputs are required, but the input trajectory tape must be the nonstandard HOPE special format 3 tape which contains, in addition to the standard APE input trajectory synchronized with the IR radiometer scan center crossings, the instantaneous IR scanner radiometer shaft rotation rate, ω, in radians/second at each trajectory time point T_{ci}. The rotation rates are double precision words added as DUM82(44), the 44th double precision word of each format 3 trajectory data record. The nonstandard format 3 trajectory tape can be prepared by the HPEINT program (see Reference 2).

The IR scanner mounting angles are set in the APE program as RHO = ρ = 270.0 degrees, DOQ = γ = (90.0 - ϕ) degrees, and DOR = δ = 90.0 degrees; where the ϕ = PHIIRS should be input through the namelist/INPUT1/ input if ϕ is not zero. The SIM-bay Infrared Scanning Radiometer roll position angle, PHIIRS' = ϕ, is 40.416667 degrees for Apollo 17. Geometrically, this angle is the same as the SIM-bay mapping camera mounting angle (Figure 2-3), differing only in magnitude.

This special application of APE deviates from the generalized APE program flow only in the compositions and formats of the online and tape outputs. The online outputs is a truncation of the standard APE output, with outputs for each computational point restricted to computational point number (frame number), computational time (CTE in hours, minutes, and seconds and GMT in years, months, days, hours, minutes, and sec[illegible]), spacecraft state vector (km and km/sec) as defined in both the sele[illegible]hic and the mean of 1950 moon centered inertial coordinate systems. [illegible]e output is composed of three parts, a single leading title record, a variable number of data records, and a concluding flag record. The formats of the title record and the flag record are the same as that of HOPE trajectory tape (format 3) or APE standard D-output tape. The format of the data record is defined in such a way that each physical record contains nine logical records and each logical record consists of 28 single precision words as shown in Table 4-16.

2.2.3 Lunar Sounder

This special application of APE is for the production of synchronized spacecraft state vector and attitude data for support of the Apollo Lunar Sounder experiment. With the exception of the program alter deck specified in Appendix A.2, the inputs required are identical with the $INPUT, for the SIM-bay mapping camera. For this application, data cards are not required. The only deviation from the generalized APE program flow is in the online print and tape outputs. The online print for each computational point is restricted to computational time (CTE and GMT), spacecraft state vector (mean of 1950 and selenographic), nadir point position (latitude and longitude), and spacecraft gimbal angle values. These same parameters, excluding CTE, are output to two tapes assigned to units E and F. The output to the E tape is formatted for subsequent translation to a 9-track EBCDIC tape for use as input to an IBM 360 computer program. The output to the F tape is unformatted binary. Both output tapes are 7 track. Tape outputs are as defined in Tables 4-17 and 4-18.

3. PROGRAM STRUCTURE

3. PROGRAM STRUCTURE

The APE main program, APEVAL, can be executed only by calling the MAP (Memory Allocation Processor) Tl. It specifies program partitioning and core allocation. APEVAL allocates core to the program overlay only when necessary; otherwise, its core allocation is restricted to APECOM and its supporting subroutines. The APEVAL flow is shown in Figure 3-1.

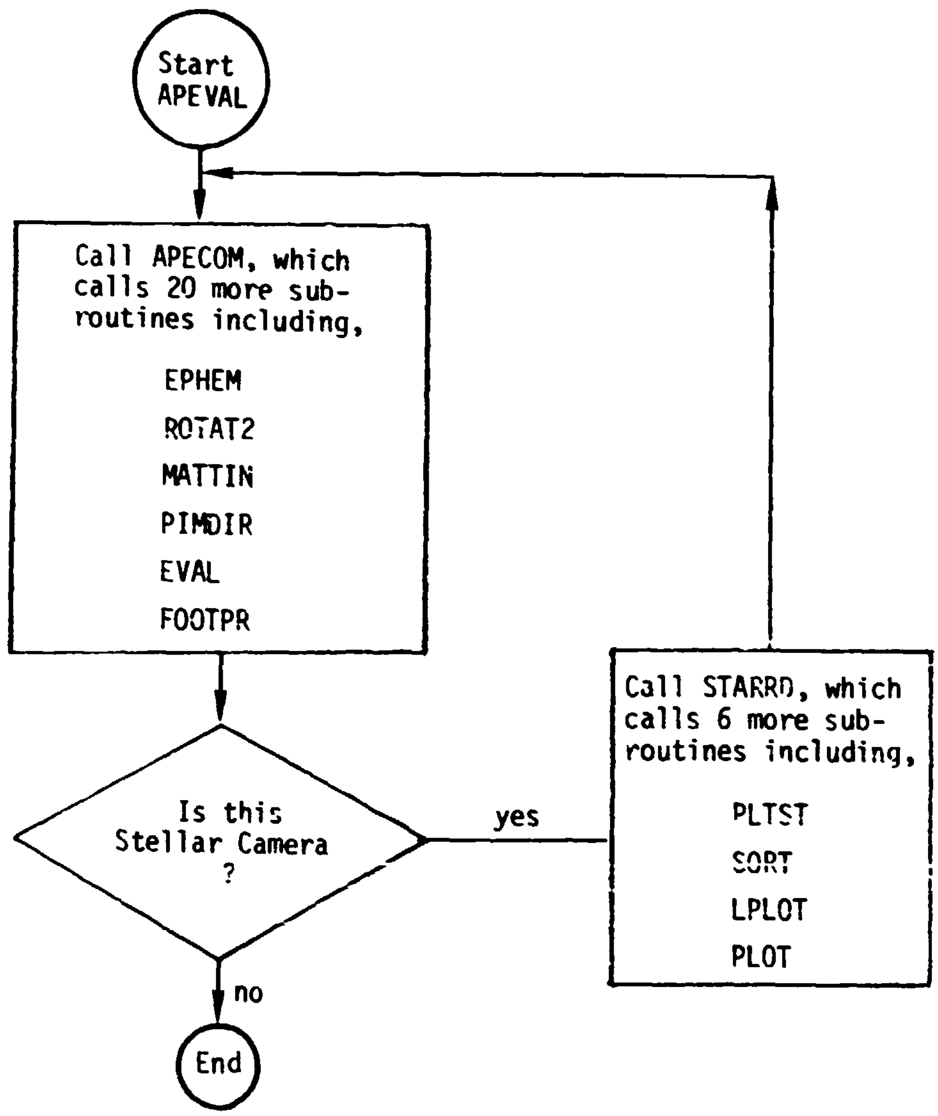


Figure 3-1. APEVAL Program Flow

3.1 OVERLAY STRUCTURE

The use of APE for the Apollo stellar camera requires a program overlay structure. This is due to the unusually high core requirements of the star catalog search, star coordinate definition manipulations, and star pattern plot construction.

With these high core demands, any attempt at single line allocation will result in core memory overflow.

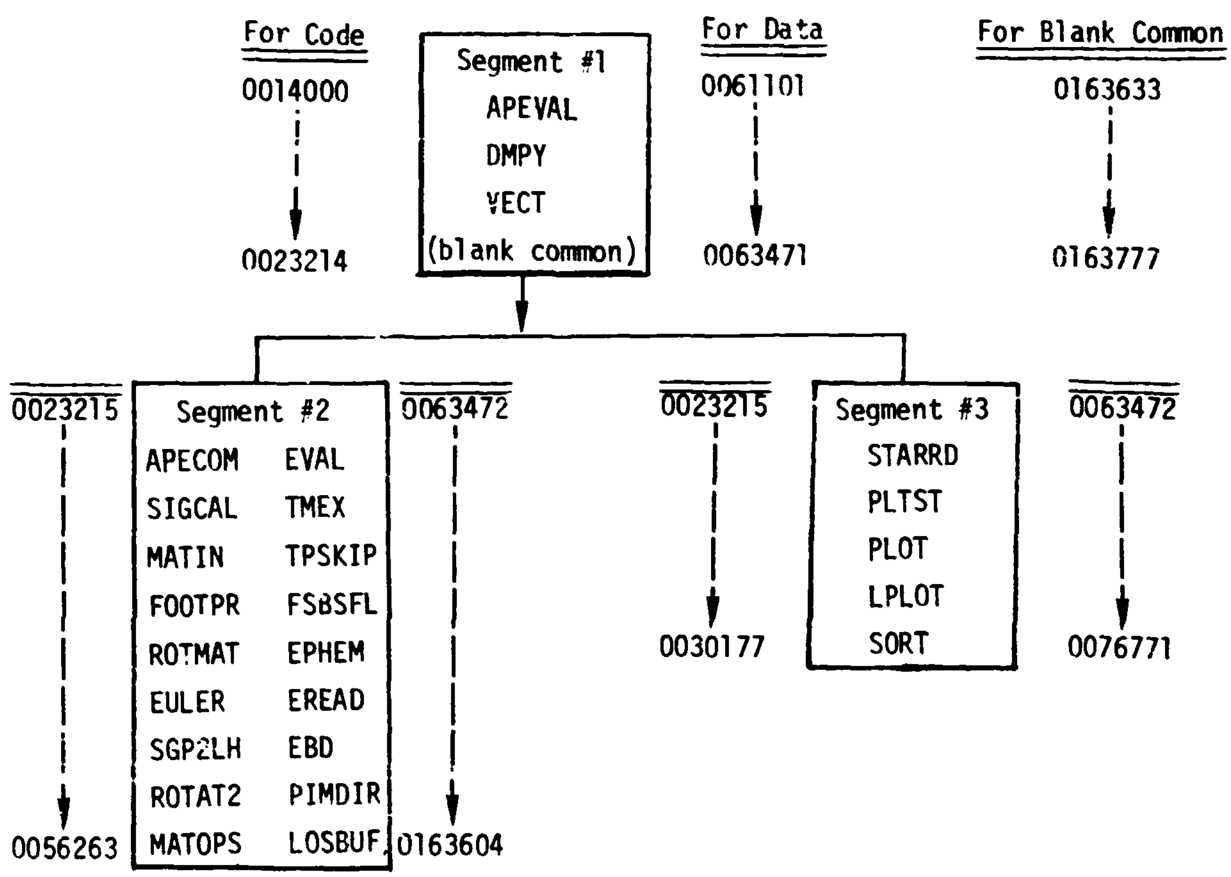


Figure 3-2. Overlay Structure for APE

APE is partitioned as shown in Figure 3-2. The first segment contains APEVAL, DMPY, and VECT. The core location assignments in octal for this segment are 0014000 to 0023214 for the code, from 0061101 to 0063471 for the data, and from 0163633 to 0163777 for the blank common.

The second segment contains APECOM and 17 other subroutines. The core location assignments for this segment are from 0023215 to 0056263 for the code and from 0063472 to 00163604 for the data.

The third segment includes STARRD, PLTST, PLOT, LPLOT, and SORT. The core location assignments for this segment are 0023215 to 0030177 for code and from 0063472 to 0076771 for data,

The second and third segments overlay each other in APEVAL for the Apollo stellar camera case (for the case of ISLT 1,ISHFTR = 3).

3.2 SUBROUTINE DEPENDENCIES

This subsection contains a dependency chart of APE elements and a dependent element cross-reference table. In both cases the entry point name has been used instead of the element name where the entry point name differs from the element name.

3.2.1 Dependency Chart

- APEVAL
  - APECOM
    - CROS
    - DMPY
    - EBD
    - EPHEM
      - EREAD
      - EREAD1
    - EPHEMI
      - EREAD
      - EREAD1
    - EULER
    - EVAL
      - CROS
      - DMPY
      - UNIT
      - VDOT
    - FOOTPR
      - DMPY
      - UNIT
    - MATIN
    - MTRN
    - PIMDIR - LODBUF
    - ROTAM2 - ENUTE
      - EREAD
      - EREAD1
    - ROTAT2 - ENUTE
      - EREAD
      - EREAD1
    - ROTMAT - DMPY
    - SGP2LH
    - SIGCAL - DMPY
    - TMEX
    - TPSKIP
    - UNIT
    - VDOT
  - STARRD
    - DMPY
    - PLTST
      - LPLOT
      - PLOT
      - SORT
    - VDOT

3.2.2 Dependent Element Cross-Reference

Name, Entry & Element	Referenced By These Elements					
APECOM	APEVAL					
CROS	APECOM	EVAL				
DMPY	APECOM	EVAL	FOOTPR	ROTMAT	SIGCAL	STARRD
EBD	APECOM					
ENUTE (EPHEM)	GHA2	ROTAM2	ROTAT2			
EPHEM (EPHEM)	APECOM					
EPHEMI (EPHEM)	APECOM					
EREAD (EREAD)	ENUTE	EPHEM	EPHEMI			
EREADI (EREAD)	ENUTE	EPHEM	EPHEMI			
EULER	APECOM					
EVAL	APECOM					
FOOTPR	APECOM					
LODBUF	PIMDIR					
LPLOT	PLTST					
MATIN	APECOM					
MTRN (MATOPS)	APECOM					
PIMDIR	APECOM					
PLOT	PLTST					
PLTST	STARRD					
ROTAT2 (ROTAT2)	APECOM					
ROTAM2 (ROTAT2)	APECOM					
ROTMAT	APECOM					
SGP2LH	APECOM					
SIGCAL	APECOM					
SORT	PLTST					
STARRD	APEVAL					
TMEX	APECOM					
TPSKIP	APECOM					
UNIT	APECOM	EVAL	FOOTPR			
VDOT	APECOM	EVAL	STARRD			

3.3 VARIABLE DEFINITIONS

Any variable in a subroutine can be classified in various ways. For example,

a.	Common variable	(CV)
b.	Input/output variable into/from each subroutine	(IS/OS)
c.	APE program input variable	(IV)
d.	APE program output variable	(CV)
e.	Unused variable (left over from previous version)	(TV)
f.	Internal variable in each subroutine	(SV)

In this document, the above example convention has been adopted and the abbreviated symbols in the parentheses will be used in this and later sections.

Item (a), the common variables, is listed under each common block name in Section 3.4.

Item (b), the input and output variables under each subroutine subtitle of the few selected principal subroutines, will be discussed in detail in Section 3.5.

Item (c), the APE program input variables supplied to APE by way of namelist, input data card, or input tape, is discussed in detail in Section 4.1. Among those IS variables, a number of dummy program input variables are identified and listed. Table 4-4 is a list of the TV variables.

Item (d), the APE program output variables which are written by APE on output units, tape, or on-line (but not on punched card form), will be discussed in detail in Section 4.2.

Item (e), the unused variables which are present in the various subroutines, will be discussed together with special cases of items a, b, c, or d. The TV variables must be identified if they also are IV or IS. This is necessary, because the TVs are not hidden left over variables but are visible input variables which need to be identified.

Item (f), the internal variables in each subroutine, will be discussed only if they are computed in the subroutines described in Section 3.5. In this document, SV includes OV but excludes IV.

3.4 COMMON VARIABLES

APE has 19 common blocks including a blank common but uses only the blank common and 11 labeled commons. The common blocks used are listed below.

Common Label Name	Elements Referenced		
blank common	APECOM	EVAL	STARRD
AET	APECOM	EVAL	
BDGENI	APECOM	EVAL	EBD
CONST	APECOM	EVAL	
EVIN	APECOM	EVAL	
GDATA	APECOM	EVAL	
KOPAN	APECOM	LODBUF	
OMEGAI	APECOM	EVAL	
PAP	APECOM	EVAL	
SGTOCM	APECOM	EVAL	FOOTPR
SIGVAR	APECOM	SIGCAL	
STRECD	PLTST	STARRD	

The follow seven common blocks are not used and are given no further consideration here.

Unused Common	Elements Referenced	
BCBIG	APECOM	EBD
BCMAN	APECOM	EBD
BDNP	EBD	
BCNPTS	APECOM	EBD
BCR	EBD	
BCTGT	APECOM	EBD
MASTER	APECOM	

3.4.1 Blank Common Block

The blank common block is used in three subroutines, APECOM, EVAL and STARRD. It contains the following fifty-five CV, mixed mode variables.

```
    COMMON//IPRS
    COMMON//ALOW, AHIGH, DLOW, DHIGH, MTAPE, DELT, BRILL, INUM, TEMPG, RABER
 1, CFL, T3, NINV, K1, K2, STEROT
 2, JDYSHP, LCHJD, TSTART, TSTOP, IFIRST, DELTME
 3, HPETME
```

Common Variable (CV) Name	Dimension	Position	Type	Description (section where defined)
IPRS	0	1	I	IV/APECOM, IS/EVAL (§ 4.1.1).
ALOW	0	2-3	D.P.	SV/APECOM, AL/SV/STARRD.
AHIGH	0	4-5	D.P.	SV/APECOM, AH/SV/STARRD.
DLOW	0	6-7	D.P.	SV/APECOM, DL/SV/STARRD.
DHIGH	0	8-9	D.P.	SV/APECOM, DH/SV/STARRD.
MTAPE	0	10	I	IV/APECOM, IS/STARRD (§ 4.1.1).
DELT	0	11	Real	IV, CV not used.
BRILL	0	12	Real	SV/STARRD, CV and IV not used.
INUM	0	13	I	SV/STARRD, CV not used.
TEMPG	0	14-15	D.P.	SV/APECOM, IS/STARRD.
RABER(I)	3	16-21	D.P.	SV/APECOM, IS/STARRD.
CFL	0	22	Real	IV/APECOM, SV/EVAL, IS/STARRD.
T3(I,J) = NMTRX(I,J)	(3,3)	23-40	D.P.	SV/APECOM, IS/STARRD.
NINV(I,J)	(3,3)	41-58	D.P.	SV/APECOM, IS/STARRD (=STEROT(I,J)).
K1	0	59	Real	SV/APECOM, IS/STARRD, XK1/IS/PLTST.
K2	0	60	Real	SV/APECOM, IS/STARRD, XK2/IS/PLTST.
STEROT(I,J)	(3,3)	61-78	D.P.	SV/APECOM, IS/STARRD.

Blank Common Block (Continued)

Common Variable (CV) Name	Dimension	Position	Type	Description (section where defined)
JDYSHP	0	79-80	D.P.	OS/TMEX, SV/APECOM, CV not used.
LCHJD	0	81-82	D.P.	OS/TMEX, SV/APECOM, CV not used.
TSTART	0	83-84	D.P.	SV/APECOM, CV not used.
TSTOP	0	85-86	D.P.	SV/APECOM, CV not used.
IFIRST	0	87	I	SV/APECOM, CV not used.
DELTME	0	88-89	D.P.	SV/APECOM, CV not used.
HPETME(I)	6	90-101	D.P.	IV/APECOM, CV not used (§ 4.1.2).

3.4.2 Common/AET/

The labeled common/AET/ is used in two subroutines, APECOM and EVAL. There is only one double precision variable in this common block.

COMMON/AET/GNTME

Common Variable (CV) Name	Dimension	Position	Type	Description
GNTME	0	1-2	D.P.	G&N time in seconds, defined as GNTME = 60.*TGIMBL - BASTIM. SV/APECOM,IS/EVAL

3.4.3 Common/BCGENI/

The labeled common/BCGENI/ is used in three subroutines, APECOM, EBD, and EVAL. It contains 35 single precision, real variables. All except the first four variables are TV; i.e., unused variables.

```
COMMON/BCGENI/GM, RMOON1, ETUT, RA,
XCC(4), CCC(9), CANO(2), CAM(7)
X,D(2), APL(2), APW(2), CAMA(3)
```

Name of Common Variable (CV) Used in APE	Dimension	Position	Type	Description
GM = UM	0	1	Real	IV/APECOM, moon's gravitational constant (km^3/sec^2)
RMOON1 = RM	0	2	Real	SV/APECOM, moon's local radius (km)
ETUT	0	3	Real	SV/APECOM, ETUT = DETUT*60.0 (min)
RA = REARTH	0	4	Real	SV/APECOM, RA = RE (km)
CC(I)	4	5-8	Real	TV
CCC(I)	9	9-17	Real	TV
CANO(I)	2	18-19	Real	TV
CAM(I)	7	20-26	Real	TV
D(I)	2	27-28	Real	TV
APL(I)	2	29-30	Real	TV
APW(I)	2	31-32	Real	TV
CAMA(I)	3	33-35	Real	TV

3.4.4 Common/CONST/

The labeled common/CONST/ is used in two subroutines, APECOM and EVAL. It contains five mixed mode variables. The first three variables are conversion factors assigned through data statements in APECOM.

COMMON/CONST/KM2FT,ET2FT,DTOR,F,MN

Name of CV	Dimension	Position	Type	Description
KM2FT	0	1-2	D.P.	SV/APECOM, KM2FT = 5702383.60832D + 0
ER2FT	0	3	Real	SV/APECOM, ER2FT = 20925738.19E + 0
DTOR	0	4-5	D.P.	SV/APECOM, DTOR = 0.017453292519943D + 0
F	0	6	Real	SV/APECOM, F = CFL (IV/APECOM)
MN	0	7	I	SV/APECOM, MN = MISSNO (IV/APECOM)

3.4.5 Common/EVIN/

The labeled common/EVIN/ is used in two subroutines, APECOM and EVAL. It contains eight double precision variables which are all calculated in APECOM and are transferred into EVAL as 1S/EVAL. The units of PM(I) and ZJ(I) are converted from feet to km in EVAL.

COMMON/EV IN/DPHANG, SUNELV, RMBAR, ZJ

Name of CV	Dimension	Position	Type	Description
DPHANG = RHO	0	1-2	D.P.	SV/APECOM, phase angle in radians
SUNELV	0	3-4	D.P.	SV/APECOM, sun elevation angle in radians
RMBAR(1) = PM(I)	3	5-10	D.P.	SV/APECOM, unit vector of surface vertical at principal ground point
ZJ(I)	3	11-16	D.P.	SV/APECOM, unit vector of camera optical axis

3.4.6 Common/GDATA/

The labeled common/GDATA/ is used in two subroutines, APECOM and LODBUF. It contains 9,074 mixed mode variables. Ten of these variables, ELEMDO(1) and (2), ELEMDI(1) and (2), ELEMDM(1) and (2); and ITRUN(1)...(4) are TV and 3007, SHAFT(1)...(500), TRUN(1)...(1,000), STIME(1)...(501), TTIME(1) ..(1,000), ISHFTR, ISHFT(1)...(4) and ITELE are not CV in the true sense since they are not used in the subroutine LODBUF.

```
      COMMON/GDATA/TGO, TGI, TGM, TGOTME, TGITME, TGMTME, SHAFT, TRUN, STIME
   1, TTIME, IOUTER, IINNER, IMID, ELEMDO, ELEMDI, ELEMDM
   2, ITNOW, GBTMIN, ISHFTR
   3, ISHFT(4), ITRUN(4)
   4, TDATA, BTRTL, BTRTH
   5, ITELE
   6, INDX
```

Name of CV	Dimension	Position	Type	Description
TGO(I)	1000	1-2000	D.P.	SV/APECOM, IS, SV/LODBUF
TGI(I)	1000	2001-4000	D.P.	SV/APECOM, IS, SV/LODBUF
TGM(I)	1000	4001-6000	D.P.	SV/APECOM, IS, SV/LODBUF
TGOTME(I)	1000	6001-8000	D.P.	SV/APECOM. IS, SV/LODBUF
TGITME(I)	1000	8001-10000	D.P.	SV/APECOM, IS, SV/LODBUF
TGMTME(I)	1000	10001-12000	D.P.	SV/APECOM, IS, SV/LODBUF
SHAFT(I)	500	12001-13000	D.P.	SV/APECOM, IS/PIMDIR, TV/LODBUF (CV not used)
TRUN(I)	1000	13001-15000	D.P.	SV/APECOM, IS/PIMDIR, TV/LODBUF (CV not used)
STIME(I)	501	15001-16002	D.P.	SV/APECOM, IS/PIMDIR, TV/LODBUF (CV not used)
TTIME(I)	1000	16003-18002	D.P.	SV/APECOM. IS/PIMDIR, TV/LODBUF (CV not used)
IOUTER(I)	4	18003-18006	I	IV/APECOM, IS/LODBUF

3.4.6 Common/GDATA/ (Continued)

Name of CV	Dimension	Position	Type	Description
IINNER(I)	4	18007-18010	I	IV/APECOM, IS/LODBUF
IMID(I)	4	18011-18014	I	IV/APECOM, IS/LODBUF
ELEMDO(I)	2	18015-18016	Real	TV
ELEMDI(I)	2	18017-18018	Real	TV
ELEMDM(I)	2	18019-18020	Real	TV
ITNOW	0	18021	I	IV/APECOM, IS/LODBUF
GBTMIN	0	18022-18023	D.P.	SV/APECOM, IS/LODBUF
ISHFTR	0	18024	I	IV/APECOM, TV/LODBUF (CV not used)
ISHFT(I)	4	18025-18028	I	IV/APECOM, TV/LODBUF (CV not used)
ITRUN(I)	4	18029-18032	I	TV
TDATA(K,J)	(4,10)	18033-18072	Real	IV/APECOM, IS/LODBUF
BTRTL	0	18073	Real	IV/APECOM,(also set BTRTL = .10), IS/LODBUF
BTRTH	0	18074	Real	IV/APECOM (also set BTRTH = .02), IS/LODBUF
ITELE	0	18075	I	IV/APECOM, TV/LODBUF (CV not used)
INDX	0	18076	I	SV/APECOM, IS/LODBUF

3.4.7 Common/KOPAN/

The labeled common/KOPAN/ is used in two subroutines, APECOM and EVAL. It has the single integer mode variable KOPAN. For all APE applications other than those for which ISHFTR = 4 (panoramic camera), KOPAN is TV and needs no further consideration. For these applications where ISHFTR = 4 (panoramic camera), KOPAN is read in from the fifth card group at sequence number 389 of APECOM. Note that the second character of the variable title is zero and not the letter O.

COMMON/KOPAN/KOPAN

Name of CV	Dimension	Position	Type	Description
KOPAN	0	1	I	IV, IS/APECOM, IS, OS/EVAL

3.4.8 Common/OMEGAI/

The labelled common/OMEGAI/ is used in two subroutines, APECOM and EVAL. It has one double precision variable, OMEGAI which is the IR scanner instantaneous rotational rate in radians/second and is supplied to APECOM from the non-standard special trajectory FORMAT3 data tape as DUM82(44).

COMMON/OMEGAI/OMEGAI/

Name of CV	Dimension	Position	Type	Description
OMEGAI	0	1-2	D.P.	SV/APECOM, IS/EVAL

3.4.9 Common/PAP/

The labeled common/PAP/ is used in two subroutines, APECOM and EVAL. It contains the following 186 mixed mode variables:

```
 COMMON/PAP/DUM9, DCSVSG, DUM18, DUM28, DUM30, ALTIM, PFOOT, IRAHRS,
*          IRAMIN, RASEC, IRADC, IDECDG, IDECMN, DECSEC, IDAY, IHR, IMIN,
*          FSEC, IFRAME, TILT, AZM, LONG, LAT, CMLAT, CMLNG, ELVS, PHANG,
*          SAZ, PHI, OMEGA, KAPPA, TITLE, COPT, GMTYR, GMTMTH, GMTDAY,
*          GMTHR, GMTMIN, GMTSEC, IRFLAG
```

Name of CV	Dimension	Position	Type	Description
DUM9(I)	9	1-18	D.P.	All TV, except DUM9(1), (2), and (5); SV/APECOM, IS/EVAL IS/EVAL
DCSVSG(I)	3	19-24	D.P.	SV/APECOM, IS/EVAL
DUM18(I)	18	25-42	Real	All TV, except DUM18(10...(18), SV/APECOM, OV/EVAL
DUM28(I)	28	43-98	D.P.	
DUM28(1)	-	-	-	SV/APECOM, TV/EVAL (CV not used)
DUM28(2)...(3)	-	-	-	TV
DUM28(4)...(6)	-	-	-	DVEL(1)...(3)/IV/APECOM, TV/EVAL (CV not used)
DUM28(7)...(10)	-	-	-	TV
DUM28(11)...(16)	-	-	-	SV/APECOM, IS, OV/EVAL
DUM28(17)...(19)	-	-	-	TV
DUM28(20)...(25)	-	-	-	SV/APECOM, IS/EVAL
DUM28(26)...(28)	-	-	-	TV
DUM30(I)	30	99-158	D.P.	

3.4.9 Common/PAP/ (Continued)

Name of CV	Dimension	Position	Type	Description
DUM30(1)...(3)	-	-	-	SV/APECOM, TV/EVAL (CV not used)
DUM30(4)...(6)	-	-	-	SV/APECOM, IS, OV/EVAL, X-, Y-tilts and heading
DUM30(7)...(9)	-	-	-	SV/APECOM, TV/EVAL (CV not used)
DUM30(10)...(18)	-	-	-	SV/APECOM, IS, OV/EVAL, LH2CM(1.1) ...(LH2CM(3.3)
DUM30(19)...(27)	-	-	-	SV/APECOM, IS, OV/EVAL, SC2CM(1.1) ...SC2CM(3.3)
DUM30(28)...(30)	-	-	-	SV/APECOM, TV/EVAL (CV not used)
ALTIM(I)	3	159-161	Real	SV/APECOM, IS, OV/EVAL, laser vehicle altitude in km
ALTIM(2)	-	-	-	SV/APECOM, IS, OVEVAL, laser slant range in km
ALTIM(3)	-	-	-	TV
PFOOT(I)	(8,7)	162-217	Real	SV/APECOM, IS, OVEVAL, latitude and longitude of footprints
IRAHRS	0	218	I	SV/APECOM, IRA(1)/OV/EVAL, right ascension (hr)
IRAMIN	0	219	I	SV/APECOM, IRA(2)/OV/EVAL, right ascension (min)
RASEC	0	220	Real	SV/APECOM, OV/EVAL, right ascension (sec)
IRADC	0	221	I	SV/APECOM, IS/EVAL, print flag
IDECDG	0	222	I	SV/APECOM, OV/EVAL, declination (deg)

3.4.9 Common/PAP/ (Continued)

Name of CV	Dimension	Position	Type	Description
IDECMN	0	223	I	SV/APECOM, OV/EVAL, declination (min)
DECSEC	0	224	R	SV/APECOM, OV/EVAL, declination (sec)
IDAY	0	225	I	SV, IV, OV/APECOM, OV/EVAL
IHR	0	226	I	IV, SV, OV/APECOM, OV/EVAL
IMIN	0	227	I	IV, SV, OV/APECOM, OV/EVAL
FSEC	0	228	Real	SV, IV, OV/APECOM, OV/EVAL
IFRAME(I)	2	229-230	I	
IFRAME(1)	-	-	-	IV, SV. OV/APECOM, K/OV/EVAL
IFRAME(2)	-	-	-	IV, SV, OV/APECOM, TV/EVAL (CV not used)
TILT	0	231	Real	SV, OV/APECOM, OV/EVAL, tilt angle (deg)
AZM	0	232	Real	SV, OV/APECOM, SV, OV/EVAL, tilt azimuth (deg)
LONG	0	233	Real	SV, OV/APECOM, XLO/SV, OV/EVAL, longitude of nadir point
LAT	0	234	Real	SV, OV/APECOM, XLA/SV, OV/EVAL, latitude of nadir point
CMLAT	0	235	Real	SV, OV/APECOM, XLAC/OV/EVAL, latitude camera axis
CMLNG	0	236	Real	SV, OV/APECOM, XLOC/OV/EVAL, longitude camera axis intersection
ELVS	0	237	Real	SV, OV/APECOM, SV/EVAL

3.4.9 Common/PAP/ (Continued)

Name of CV	Dimension	Position	Type	Description
PHANG	0	238	Real	SV, OV/APECOM, PHASE/OV/EVAL (deg)
SAZ	0	239	Real	SV, OV/APECOM, SAI/OV/EVAL, sun azimuth
PHI	0	240	Real	SV, /APECOM, OV/EVAL (deg)
OMEGA	0	241	Real	SV, /APECOM, OV/EVAL (deg)
KAPPA	0	242	Real	SV, /APECOM, OV/EVAL (deg)
TITLE(I)	4	243-246	Real	IV, OV/APECOM, OV/EVAL
COPT(I)	3	247-252	D.P.	SV/APECOM, SV/EVAL, spacecraft direction cosines
GMTYR	0	253	I	SV, OV/APECOM, IGMT(1)/OV/EVAL
GMTMTH	0	254	I	SV, OV/APECOM, IGMT(2)/OV/EVAL
GMTDAY	0	255	I	SV, OV/APECOM, IGMT(3)/OV/EVAL
GMTHR	0	256	I	SV, OV/APECOM, IGMT(4)/OV/EVAL
GMTMIN	0	257	I	SV, OV/APECOM, IGMT(5)/OV/EVAL
GMTSEC	0	258-259	D.P.	SV, OV/APECOM, OV/EVAL
IRFLAG	0	260	I	SV, /APECOM, SV/EV

3.4.10 Common/SGTOCM/

The labeled common/SGTOCM/ is used in three subroutines, APECOM, EVAL, and FOOTPR. It contains nine double precision variables which are the elements of the transformation matrix, SG2CM(3,3).

COMMON/SGTOCM/SG2CM

Name of CV	Dimension	Position	Type	Description
SG2CM(I,J)	(3,3)	1-18	D.P.	SV/APECOM, IS/EVAL, IS/FOOTPR

3.4.11 Common/SIGVAR/

The labeled common/SIGVAR/ is used in two subroutines, APECOM and SIGCAL. It contains 99 double precision variables and is used only for special IR scanner applications.

COMMON/SIGVAR/PUIVK, PUIVKT, LAMDAC

Name of CV	Dimension	Position	Type	Description
PUIVK(I,J)	(1,9)	1-18	D.P.	SV/APECOM, IS, SV/SIGCAL
PUIVKT(I,J)	(9,1)	19-36	D.P.	TV/APECOM, SV/SIGCAL (CV not used)
LAMDAC(I,J)	(9,9)	37-198	D.P.	SV/APECOM, IS, SV/SIGCAL

3.4.12 Common/STRECD/

The labeled common/STRECD/ is used in two subroutines, PLTST and STARRD. It contains Z(5,200) or C(5,200) single precision variables for use in the star patterns. They are selected from the star catalog by STARRD and are used in PLTST.

COMMON/STRECD/Z or COMMON/STRECD/C

Name of CV	Dimension	Position	Type	Description
Z(I,J) = C(I,J)	(5,200)	1-1000	Real	SV/STARRD, IS, SV/PLTST
C(1,J)	-	-	-	Y- diapositive coordinate of Jth star
C(2,J)	-	-	-	X- diapositive coordinate of Jth star
C(3,J)	-	-	-	Magnitude of Jth star
C(4,J)	-	-	-	BOSS number of Jth star
C(5,J)	-	-	-	SAO number of Jth star

3.4.13 Unused Common Blocks

The following seven common blocks containing 3,090 variables in mixed modes are not used and should be ignored.

Name of TV Common Block	Name of Variables	Dimension	Position	Type	Elements Referenced
BCBIG	BIG(I)	100	1-100	Real	TV/APECOM, TV/EBD
BCMAN	MAN(I)	30	1-30	Real	TV/APECOM, TV/EBD
BCNP	XNPH(I)	480	1-480	Real	TV/EBD
	XNPL(I)	420	481-900	Real	TV/EBD
BCNPTS	NPTS(I)	370	1-370	Real	TV/APECOM, TV/EBD
BCR	R(I)	100	1-100	Real	TV/EBD
	RID(I)	20	101-120	Real	TV/EBD
	RZ(I)	100	121-220	Real	TV/EBD
BCTGT	TGT(I)	10	1-1	Real	TV/APECOM, TV/EBD
MASTER	IPOINT(I)	120	1-120	I	TV/APECOM
	CONST(I)	450	121-1020	D.P.	TV/APECOM
	KONST(I)	120	1021-1140	I	TV/APECOM
	CONFIX(I)	320	1141-1460	Real	TV/APECOM
	KONFIX(I)	450	1461-1910	I	TV/APECOM

3.5 SUBROUTINE DESCRIPTION

This section briefly describes each of the 27 elements used by APE. APE has one main program, APEVAL, the element with an asterisk (*): one MAP, T1, the elements with blocks; 25 subroutines which have 39 entry points all together; and one function routine, PIMDIR, which is underlined. Those with parentheses, such as (EPHEMI) or (ENUTE), are the additional routine entries which differ from the element name.

Name of Element	Description
APECOM	Computes vehicle-instrument-moon geometry and target lighting
APEVAL*	Main driving program of APE
DMPY	Multiplies double precision matrices of the form A•B
EBD	Initializes the constant array
EPHEM (EPHEMI) (ENUTE)	Reads and interpolates JPL planetary ephemeris
EREAD (EREADI)	Reads the data record containing the date from JPL ephemeris tape
EULER	Computes Euler angles from the LH2CM rotation matrix
EVAL	Output processor of APE
FOCTPR	Computes the footprints which are the projections of points on the photo format onto the mean lunar surface
LODBUF	Reads and buffers the input telemetered data
LPLOT	Loads plot array for star pattern
MATIN	Matrix inversion routine
MATOPS	A multi-entry point, matrix operations routine
(MSUBT) (MADDA) (MMOV) (MTRN) (MMPY)	Subtraction : C = A-B Addition : C = A+B Move and copy : C = A Transpose : C = A^T Multiplication: C = A•B

Name of Element	Description
PIMDIR	A four point interpolation function routine
PLOT	Plots an online star pattern
PLTST	Tabulates data for plotted stars
ROTAT2	Rotates a vector from one time based coordinate system to another
(ROTAM2)	Computes rotation matrices necessary to rotate from one coordinate system to another coordinate system
(GHA2)	Computes Greenwich hour angle
RCTMAT	Rotates the camera axes coordinate system about its Z-axis to position its X-axis to lie within 45° of the velocity vector direction
SGP2LH	Computes SG2LH rotation matrix from selenographic input vector
SIGCAL	Computes σ_{ϕ}, σ_{Ω}, σ_{TX}, σ_{KAP}, σ_{TILT}, σ_{ASM}, σ_{TY}, σ_{NDG}, or σ_{SNG}
SORT	Sorts the star array in preparation for the star pattern plot
STARRD	Reads star catalog tape and selects the brighter stars within the stellar camera FOV
SUBPAC	Calculates partial derivative terms for the sigma definitions
[T1]	MAP for the partitioning and overlaying of APE
TPSKIP	Skips pseudo end-of-files (EOR) of HCPE trajectory special format 3 tape
TMEX	Converts year, month, day of Julian date
VECT	A multi-entry point, double precision vector operation routine
(UNIT)	$\overline{V}_3$ = Unit ($\overline{V}_1$)
(VDOT)	e = $\overline{V}_1 \bullet \overline{V}_2$
(CROS)	$\overline{V}_3 = \overline{V}_1 \times \overline{V}_2$
(SDOT)	$V_3 = a\overline{V}_1$

The following are brief structured descriptions of the four major computational elements of APE. These are the subroutines APECOM, EVAL, STARRD, and FOOTPR.

3.5.1 APECOM

- PURPOSE - Computes photo analysis support data from vehicle trajectory and attitude information

- COMMON - /blank/, /AET/, /CGENI/, /CONST/, /EVIN/, /GDATA/, /KOPAN/, /OMEGAI/, /PAP/, /SGTOCM/, and /SIGVAR/ (unused common: MASTER, BCBIG, BCMAN, BCMPTS, BCTGT)

- USAGE - Call APECOM (ISLT, ASTAR, ZROT, CTM, STM)

  (IS) - Calling sequence: none
  - Common : none

  (OS) - Calling sequence: ISLT $\begin{Bmatrix} = 0 \text{ with no stellar camera} \\ \geq 2 \text{ with stellar camera} \end{Bmatrix}$

  ASTAR(1,1)...(3,3) = BD2CM(1,1)...(3,3) = TV output

  ZROT(1,1)...(3,3) = $\begin{vmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & +1 \end{vmatrix}$ = TV output

  CTM = TV namelist input (INPUT1) = TV output

  STM = TV namelist input (INPUT1) = TV output

  - Common (blank) : IPASS = TV

  ALOW

  AHIGH

  DLOW

  DHIGH

  MTAPE = Star catalog tape unit number = IV through namelist (INPUT1)

  DELT = TV = TV output

  BRILL = not CV = TV output

  INUM = not CV = TV output

  TEMPG

  RABER

CFL

NMTRX

NINV

K1

K2

STEROT

- ROUTINES REQUIRED - PIMDIR, EBD, EPHEM, FSBSFL, TPSKIP, NTRAN, TMEX, EVAL, MTRN, DMPY, ROTAM2, SGP2LH, EULER, ROTMAT, UNIT, FOOTPR, MATIN, EPHEMI, EXIT, ROTAT2, VDOT, CROS, SIGCAL

- TAPES REQUIRED
  - Units and descriptions: A(JPL19), B(FORMAT3 TRAJ), C(GIMBAL), and D(APE output)
  - Tape rewind at: 209C 216D 223B 976A 1418D
  - Tape end of file at: 1419D
  - Tape read at: 262C 324B 347B
  - Tape write at: 329D

- ONLINE OUTPUT - At: 221 265 340 342 350 377 406 433 877 879 979 1018 1059 1062 1064 1066 1069 1071 1318 1321 1330

3.5.2 EVAL

- PURPOSE - The APE output processor which converts units, formats, and writes the photo evaluation support data for online printout and output to the tape assigned to unit D.

- COMMON - /blank/, /AET/, /BCGENI/, /CONST/, /EVIN/, /KOPAN/, /OMEGAI/, /PAP/, and /SBTODM/ (all common blocks are used effectively in subroutine EVAL).

- USAGE - Call EVAL
  - (IS)
    - Calling sequence: none
    - Common: all above nine common blocks
  - (OS)
    - Calling sequence: none
    - Common: none
  - (SV,OV)
    - A = Semi-major axis of vehicle path (km)
    - ALPHA = Reflectance longitude

ALT	= Vehicle altitude
C	= Magnitude of -ZJ
DAN	= North deviation angle
E	= Eccentricity of vehicle orbit
EPS	= Emission angle
F	= Camera focal length in same units as C
HDOT	= Mean altitude rate (km/sec)
LATLIR	= Latitude of approximate IR scanner limb crossing (leading)
LATTIR	= Latitude of approximate IR scanner limb crossing (trailing)
LONLIR	= Longitude of approximate IR scanner limb crossing (leading)
LONTIR	= Longitude of approximate IR scanner limb crossing (trailing)
NU	= True anomaly
P	= Semi-latus rectum of the vehicle orbit
R	= Vehicle radius
RDOTSG	= Vehicle velocity vector (selenographic)
RHO	= Phase angle
RM	= Local lunar radius
RSG	= Vehicle position vector (selenographic)
SF	= Scale factor
SG2CM	= Transformation matrix SGTOCM
SSLN	= Longitude of subsolar point
SSLT	= Latitude of subsolar point
SUNELV	= Sun elevation angle
SUNIT	= Sun unit vector (selenographic)
SWING	= Swing angle
TH	= Angle from instrument aiming axis at scan center time to the mean lunar horizon
TL	= Tilt to leading horizon
TT	= Tilt to trailing horizon
UM	= Moon gravitational constant
VAZ	= Azimuth of velocity vector
VTHETA	= Horizontal velocity (km/sec)

- ROUTINES REQUIRED - VDOT, CROS, UNIT, and DMPY
- TAPE REQUIRED
  - Unit and descriptions: D(APE output) tape
  - Tape operation: None
  - Tape read: None
  - Tape write at: 485D, 490D
- ONLINE OUTPUT - At:

266	272	276	282	299
301	318	322	326	330
334	338	342	346	363
365	369	373	377	380
384	388	392	395	400
403	406	410	415	421
424	426	431	440	

3.5.3 STARRD

- PURPOSE - Reads the star catalog tape and selects from it the brighter stars ' .h the values of right ascension and declination within the stellar camera field of view.
- COMMON - /blank/ and /STRECD/
- USAGE - Call STARRD (ISLT, BD2CM, ZROT, CTM, STM)
  (IS)
  - Calling sequence: ISLT = 0 with no stellar camera camera
    - = 2 with stellar camera
    - BD2CM(1,1)...BD2CM(3,3) = TV input
    - ZROT(1,1)...ZROT(3,3) = TV input
    - CTM = TV input
    - STM = TV input
  - Common (blank): IPRS = TV
    - ALOW
    - AHIGH
    - DLOW
    - DHIGH
    - MTAPE
    - DELT = TV
    - BRILL = not CV = TV input
    - INUM = not CV = TV input

TEMPG

RADER

CFL = Camera focal length (meters)

NMTRX

NINV

K1

K2

STEROT

(OS) - Calling sequence: None

- Common (STRECD) : C(1,1)...C(5,200) = OV but not OS or CV

- ROUTINE REQUIRED - DMPY, VDOT, PLTST
- TAPE REQUIRED - Units and descriptions: MTAPE (star catalog input tape); usually MTAPE = 4 for X-tape
  - Tape rewind at: 33X, 65X, 131X
  - Tape backspace at: 37X
  - Tape read at: 41X
  - Tape write: None
- ONLINE OUTPUT - At: 71, 76, 112, 115

3.5.4 FOOTPR

- PURPOSE - Calculates latitudes and longitudes of photo footprint boundary points.
- COMMON - /SGTOCM/
- USAGE - Call FOOTPR (PSG, DUM82, DWI, DLI, DI, CFL, CFOOT, RMOON)

(IS) - Calling sequence: PSG(1), (2), and (3)

DUM82(1)...(82) = TV

DWI

DLI

DI

CFL = Camera focal length

RMOON

- Common (SGTOCM): SG2CM(1,1)...(3,3)

(OS) - Calling sequence: CFOOT(1)...(8)

- Common: None

- ROUTINES REQUIRED - DMPY, UNIT
- TAPE REQUIRED - None
- ONLINE OUTPUT - None

4. USER'S GUIDE

4. USER'S GUIDE

This section presents information, instructions, and requirements for execution of the APE program on a UNIVAC 1108 computer. It includes descriptions of the required system configurations and of all card and tape inputs for the various APE application types. It also includes instructions for the preparation and assembly of all required APE inputs.

The UNIVAC 1108 system configurations required for the execution of APE are shown in Table 4-8. For the general application of APE, the required configuration is achieved through the following UNIVAC 1108 unit assignments.

Unit A - JPL ephemeris (Fastrand file)
Unit B - HOPE trajectory tape (format 3)
Unit C - Vehicle attitude data tape
Unit D - Output data tape
Unit Z - APE PCF tape

The APE input deck setup for the general application is shown in Figure 4-1. The additional I/O requirements for special applications of APE are summarized in Table 4-1.

The APE program is available on two TRW 800 bpi, 7-track magnetic tapes: TRW00157 and TRW00163. These tapes are available in the TRW ancient tape library. The first file of these tapes contains all relocatable elements while the symbolic elements are contained on the second file.

Tape TRW00157, the primary APE program tape, can be operated without any alters for the generation of support data for CSM mounted cameras. Support data for the panoramic camera and the lunar sounder is obtained by use of the proper alter decks described in Appendix A.

Tape TRW00163 is used only for IR scanner applications.

4.1 INPUT

The input deck setup required for execution of the generalized APE is shown in Figure 4-1. The detailed requirements for card and tape inputs are described in Sections 4.1.1 and 4.1.2, respectively.

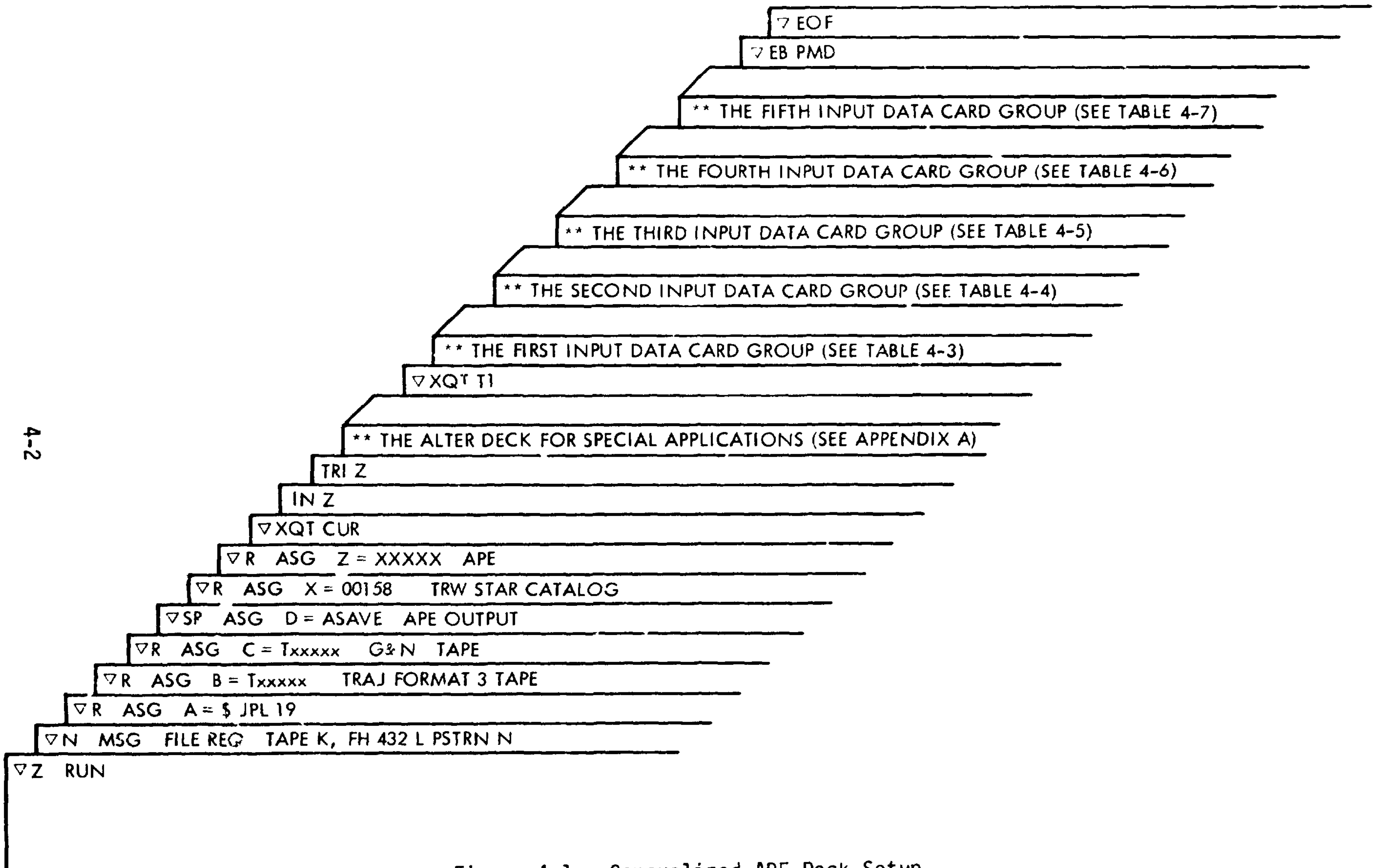


Figure 4-1. Generalized APE Deck Setup

Table 4-1. Additional I/O Requirements for APE Applications

Application (Camera or Instrument)	APE Mode (ISHFTR)	Program Alters	Additional Inputs Required	Application Outputs
Window mounted cameras	6	None	None	Standard on-line output; no output D-tape
Sextant camera	1	None	Gimbal data tape input must be in Apollo standard downlink format	Standard on-line output; no output D-tape
SIM-bay mapping camera	2	None	Third data card group (Table 4-5)	SIM-bay camera output on-line; also D-tape (Table 4-15)
Apollo panoramic camera	4	Alter deck for the panoramic camera (Appendix A.2)	Fifth data card group (Table 4-7)	Panoramic camera output on-line; also D-tape (Table 4-15)
Stellar camera	3	None	1. Third data card group 2. Star catalog tape (TRW) 3. Set ISSEQI and ISSEQF in Namelist/Input 1/	Special on-line star pattern plot and printout
Lunar sounder	2	Alter deck for the lunar sounder (Appendix A.1)	None	Two special output tapes on units E and F (Tables 4-17, 4-18); simplified on-line printout
Infrared scanner	5	None	Special trajectory tape, HOPE format 3 modified to include ω and scan center times	Special tape output on unit D (Table 4-16)

4.1.1 Card Inputs

The on-line input data card decks required for the execution of APE vary in content and order according to the program application. This is true for general as well as special applications since the input mode for two kinds of input data is optional regardless of the application type. Trajectory and vehicle attitude data may be input either by card or tape. Table 4-2 presents, in proper sequence for a generalized APE application, the basic elements of the APE input data deck. The various individual inputs of each of these elements are defined in Tables 4-3 through 4-7.

4.1.2 Tape

All the input tapes for APE are written in UNIVAC 1108 FORTRAN V binary format on 7-track, high density (800 bpi) magnetic tapes. The tape configuration for APE is shown in Table 4-8. The first three tapes, A, B, and C, are the input data tapes for a general application of APE. Tape X, the Apollo photo evaluation star catalog (TRW00158), is the input star catalog for the special stellar camera APE application. The D-tape can be the output tape for either general or special applications of APE. The last tape, Z, is the APE PCF tape (TRWXXXXX).

4.1.2.1 JPL19 Ephemeris on Fastrand File

The JPL ephemeris contains two information records at the beginning of each tape followed by the data records. The format for the data records is listed in Tabl 3-1, Section 3.2 of Reference 3. The step size of the logical data record is 8.0 days. All data, with the exception of those for nutations, are double precision so that the total record size is 1862 words.

The Julian date is the epoch (Ephemeris Time, ET) of the start of the data record. Lunar positions and velocities are referred to the geocentric equatorial rectangular reference frame of the mean equator and equinox of 1950.0 = JD 243,3282,423.

If data are required for a particular epoch in universal time (UT), the time correction DETUT = ET-UT must be specified through the namelist input (INPUT1), in minutes.

Table 4-2. Generalized Input Data Card Setup

Sequence of Input Data Card Group	Description of Input Data Card Group	Defined In	Remarks
First	Title card	Table 4-3	For all cases
Second	namelist/INPUT1/ input cards	Table 4-4	For all cases
Third	SIM-bay mapping/ stellar camera data cards	Table 4-5	For application to photographic data with ISHFTR=2 or 3
Fourth	namelist/INPUT2/ input cards	Table 4-6	For all cases of IFLAG=0 or IFLAG=2 only
Fifth	Panoramic camera data cards	Table 4-7	For ISHFTR=4 only

Table 4-3. First Data Card Group (Title Card)

Read in at Sequence #212 of subroutine APECOM with Format #1890 as (4A6,I6).

Input Variable	Columns	Format	Description
PREFIX(1)	1-6	A6	TITLE(1), the first word of the title, as CV/PAP/.
PREFIX(2)	7-12	A6	TITLE(2), the second word of the title, as CV/PAP/.
Z2 (1)	13-18	A6	TITLE(3), the third word of the title, as CV/PAP/.
Z2 (2)	19-24	A6	TITLE(4), the fourth word of the title, as CV/PAP/.
IFRAME(1)	25-30	I6	IFRAME(1), as CV/PAP/.

Table 4-4. Second Data Card Group (Namelist Input/INPUT1/)

Total 325 variables in INPUT1; 206 IV and 119TV.

Input Variable	Description	Type/Input Value(Unit)
AU	The Moon-Sun vector in astronomical units	d.p./149,597,900(km)
BTRTH	High bit rate, only for Apollo 10, 12, and 14	Real/.02(1/sec)
BTRTL	Low bit rate, only for Apollo 10, 12, and 14	Real/.10(1/sec)
CAMA(1)	FL = format length for Apollo photo frame	Real/ (mm)
CAMA(2)	FW = format width for Apollo photo frame	Real/ (mm)
CFL	Focal length	Real/ (m)
C1	Stellar camera half angle of view along Xs (forward)	d.p./ (deg)
C2	Stellar camera half angle of view along Ys (side).	d.p./ (deg)
DELTCL	Onboard clock zero (GMT) minus range zero (GMT)	Real/ (sec)
DETUT	Difference between ET (Ephemeris Time) and UT (Universal Time); (ET-UT) in minutes	d.p./ (min)
DUM82(1)...(82)	The first 82 double precision words of the data record of HOPE trajectory FORMAT3 tape	d.p./sec § 4.1.2
FL	Format length for Apollo photographic frame	Real/ (m)
FW	Format width for Apollo photographic frame	Real/ (m)
GM	Moon's gravitational constant	Real/4902.58(km^3/sec^2)
IFLAG	Input flag designating source of telemetered gimbal and vehicle state data	I/ (N.D.)

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
IFLAG (continued)	= 0 for gimbal data through cards, trajectory data through cards = 1 for gimbal data through tape, trajectory data through cards = 2 for gimbal data through cards, trajectory data through tape = 3 for gimbal data through tape, trajectory data through tape	
IGMFLE	Number of files to be skipped on the gimbal data tape	I/ (N.D.)
IINNER(1) & (2)	Word locations of inner gimbal angle in downlink buffer record	I/ (N.D.)
IINNER(3) & (4)	Element locations for timing difference computation for inner gimbal angle	I/ (N.D.)
IMID(1) & (2)	Word locations of middle gimbal angles in downlink buffer record	I/ (N.D.)
IMID(3) & (4)	Element locations for timing difference computations for middle gimbal angles	I/ (N.D.)
INT	Input flag to bypass interpolation of telemetered data. This is used only when actual telemetered values for specified times are to be used = 0 for interpolated telemetered data ≠ 0 for bypassing the interpolation of telemetered data	I/ (N.D.)

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
IOUTER(1) & (2)	Word locations of outer gimbal angles in downlink tape buffer record	I/ (N.D.)
IOUTER(3) & (4)	Element locations for timing difference computations for outer gimbal angles	I/ (N.D.)
IPROBE	Input flag for diagnostic printout = 0 for nominal printout = 1 for nominal with additional printout for detection of improper telemetered or state vector input	I/0 (N.D.)
IPRS	Number of pairs of footprint points required	I/1 (N.D.)
ISHFT(1) & (2)	Word locations of sextant shaft angles in downlink tape buffer record	I/ (N.D.)
ISHFTR	Input flag of instrument sensor (including camera) designation = 1 for sextant camera = 2 for SIM-bay mapping camera or lunar sounder = 3 for stellar camera = 4 for panoramic camera = 5 for infrared scanner = 6 for window mounted cameras	I/ (N.D.)
ISLT	Input flag for stellar camera ISLT 2 for stellar camera ISLT = 0 for nonstellar camera	I/ (N.D.)

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
ISSEQF	Input dummy frame number of star pattern (it should be a nonzero dummy frame number beyond the stop time)	I/ (N.D.)
ISSEQI	Input real frame number of star pattern to be predicted	I/ (N.D.)
ISTPRT	Print flag option for intermediate APE printout = 0 do print the intermediate printout ≠ 0 do not print the intermediate printout	I/ (N.D.)
ISVFLE	Number of files to be skipped on state vector input data tape	I/ (N.D.)
ITELE	Element location of TNOW for timing difference computations	I/ (N.D.)
ITNOW	Word location of TNOW in downlink tape buffer record	I/ (N.D.)
ITPOUT	Flag option for generation of APE output D-tape = 1 output on D-tape ≠ 1 do not create D-tape	I/ (N.D.)
LCHYR	Year of launch	I/ (year)
LCHMTH	Month of launch	I/ (month)
LCHDAY	Day of launch	I/ (day)
LCHHR	Hour of launch	I/ (hour)
LCHMIN	Minute of launch	I/ (minute)
LCHSEC	Second of launch	I/ (second)
MISSNO	Mission number	Real/ (N.D.)
MODE	The mode indicator should be = 2.0 always for the Apollo mode; otherwise, APE will be terminated	Real/ (N.D.)

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
MTAPE	The star catalog input tape (usually = 27, as X-tape)	I/ (N.D.)
OPTANG	Window-mounted camera positioning angle between the negative camera Z-axis and its projection onto the X-Y plane measured positive toward the camera axis	Real/12.0(degree)
OPTDEL	Window-mounted camera positioning angle between spacecraft body X-axis and the projection of the negative camera Z-axis onto the body X-Y plane, measured positive toward the camera axis projection	Real/ (degree)
PHIIRS	The SIM-bay IR scanning radiometer center line roll position mounting angle, ϕ, as shown in Figure 2-2	Real, 37.75(degree)
PHIMAP	The SIM-bay mapping camera center line roll position mounting angle, ϕ, as shown in Figure 2-2	Real/ (degree)
RE	Conversion factor to convert Earth radii to km	d.p./6378.165D+0(km)
RFSMAT(1,1)... (3,3)	Transformation matrix from mean of NBY to the vehicle platform coordinate system	d.p./ (N.D.)
RHO	The SIM-bay mapping camera yaw positioning angle as shown in Figure 2-2	d.p./ (degree) (set 270.0 degree only for mapping and panoramic camera)
RMOON	Moon's local radius	' p./1736.1D+0(km)
SIGBET	Uncertainty in value of inner gimbal angle	Real/ (degree)

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
SIGBPR	Uncertainty in value of sextant camera shaft angle	Real/ (degree)
SIGDEL	Uncertainty in value of window-mounted camera positioning angle δ (OPTDEL)	Real/ (degree)
SIGGAM	Uncertainty in value of window-mounted camera positioning angle γ (OPTANG)	Real/ (degree)
SIGGPR	Uncertainty in value of sextant camera positioning angle γ' (SXLAMB)	Real/ (degree)
SIGINT	Uncertainty in value of stellar camera positioning yaw angle	Real/ (degree)
SIGPMP	Uncertainty in value of stellar camera positioning pitch angle	Real/ (degree)
SIGPSI	Uncertainty in value of outer gimbal angle	Real/ (degree)
SIGRHO	Uncertainty in value of camera alignment about the camera positioning roll angle	Real/ (degree)
SIGR1	Uncertainty in first REFSMMAT rotation, $\rho 1$, about Y_{NBY}	Real/ (degree)
SIGR2	Uncertainty in secondary REFSMMAT rotation, $\rho 2$, about intermediate Z-axis	Real/ (degree)
SIGR3	Uncertainty in tertiary REFSMMAT rotation, $\rho 3$, about IMU X-axis	Real/ (degree)
SIGTAU	Uncertainty in camera shutter time	Real/ ( )

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

Input Variable	Description	Type/Input Value(Unit)
SIGTHE	Uncertainty in value of the middle gimbal angle	Real/ (degree)
SIGPR	Uncertainty in value of the sextant camera trunnion angle	Real/ (degree)
STPHR STPMN STPSC STRTHR STRTMN STRTSC	Stop and start times for desired interval of state data from tape. Used only when state data are read from tape	I/ (hour) I/ (min) Real/ (sec) I/ (hour) I/ (min) Real/ (sec)
SXLAMB	Sextant camera positioning angle between the sextant Z-axis and the spacecraft body Z-axis, measured positive from the body axis	Real/ (degree)
TAU	The excursion angle, τ, of panoramic camera	Real/ (degree)
TAUTME	The value of uncertainty in camera shutter time	Real/ (min)
TDATA(1,1)... (1,10)	The input flag, ITDAT;	Real/ (N.D.)
TDATA(2,1)... (2,10) TDATA(3,1)... (3,10) TDATA(4,1)... (4,10)	Second Minute Hour if ITDAT (=TDATA (1,i) = 0.0, then low bit rate; if ITDAT (=TDATA(1,i)) = 1.0, then high bit rate	Real/ (sec) Real/ (min) Real/ (hour)
TMAX	The maximum time between adjacent time points for data interpolation	Real/ (min)

Table 4-4. Second Data Card Group (Continued)
(Namelist Input/INPUT1/)

The following 119 variables (TVs) in namelist/INPUT1/ are not used in APE and should be ignored.

TV in the namelist/INPUT1/	TV in the namelist/
ALPC	ORBIT
APL(1) and (2)	P1
APW(1) and (2)	P2
BRILL	P12
CAM(1),(2),(3),(4),(5),(6), and (7)	PDELT
CAMA(3)	PHIC
CANQ(1) and (2)	PHIFHR
CC(1),(2),(3), and (4)	PHIFLR
CCC(1),(2),(3),(4),(5),(6),(7),(8), and (9)	PHIH
CONTRL(1),(2),(3),(4), and (5)	PHIHR
CTM	PHILR
D(1) and (2)	PSTGET(1),(2), and (3)
DELC	PTAPE
EPOCH(1),(2),(3),(4),(5), and (6)	P44
FCLHI	R12
FCLLO	RES
FLCA	SIGIHS
FRAME1	STM
FRINC	TAPE
G	TGT
G1	TGT1,TGT2,TGT3,TGT4, and TGT5
IRU	THEFHR
ITRUN(1),(2),(3), and (4)	THEFLR
KINTPC	THEHR
KONFIX	THELR
KONST	THTC
KOPAN	THTH
MAN1,MAN2,MAN3,MAN4, and MAN5	THTHF
MI	THTHS
NOF	THTLF
NOP	THTLS
NPTS	TIME1(1)...(6)
	TIME2(1)...(6)

Table 4-5. Third Data Card Group For SIM-Bay Mapping/Stellar Camera

Read in at sequences #385 and #543 with FORMAT #1787 for the SIM-bay mapping camera and at sequence #561 with FORMAT #1998 for the stellar camera.

Input Variable	Format	Columns	Description
IFRAME(1)	I4	1-4	Frame number
KZ	A1	5	Flag designation to skip the non-photo timing record in trajectory tape if KZ = "X"
IDAY	I2	8-9	Photo shutter time
IHR	I2	13-14	
IMIN	I2	18-19	
SECW	F2.0	23-24	
SECF	F3.3	26-28	
RS	F6.0	32-37	Laser altimeter slant range in (meter)

NOTE:

(i) RS is not required.

(ii) Extra cards containing "X" in column 5 have to be added to match every dummy, nonphoto timing record on the trajectory FORMAT3 tape. In this way the third data card group insures that the time tags of trajectory records and of the shutter times are matched.

Table 4-6. Fourth Data Card Group
(Namelist Input/INPUT2/)

Read in at sequence #424 if IFLAG = 0 or 2.

Input Variable	Type	Unit	Description
CSHAFT	Real	degree	β' - sextant shaft angle
CTRUN	Real	degree	θ - sextant trunnion angle
DVEL(1)	D.P.	E.R./min	$\dot{X}$ - vehicle velocity component in selenographic coordinates
DVEL(2)	D.P.	E.R./min	$\dot{Y}$ - vehicle velocity component in selenographic coordinates
DVEL(3)	D.P.	E.R./min	$\dot{Z}$ - vehicle velocity component in selenographic coordinates
INNER	D.P.	degree	β - inner gimbal angle
MIDDLE	D.P.	degree	θ - middle gimbal angle
OUTER	D.P.	degree	ψ - outer gimbal angle
POS(1)	D.P.	E.R.	X - vehicle position component in selenographic coordinates
POS(2)	D.P.	E.R.	Y - vehicle position component in selenographic coordinates
POS(3)	D.P.	E.R.	Z - vehicle position component in selenographic coordinates
TGIMBL	D.P.	min.	Gimbal time from midnight day of launch

Table 4-7. Fifth Data Card Group - Panoramic Camera Data Cards

Read in at Sequences #389 and #612 with FORMAT #1909 for the panoramic camera.

Input Variable	Format	Columns	Description
KOPAN	A1	1	The input direction designator = V for vertical positioned "mono" mode = F for forward positioned "stereo" mode = A for aft positioned "stereo" mode = X for skipping one trajectory record
IFRAME(1)	I4	2-5	Frame number (four digits)
IDAY	I2	6-7	AET shutter time for panoramic camera
IHR	I2	9-10	
IMIN	I2	12-13	
FSEC	F6.3	15-20	

NOTE:

An extra card containing an "X" in column 2 must be input to match every dummy, nonphotographic timing record of the trajectory FORMAT3 tape. In this way the third data card group insures that the time tags of the trajectory records and of the panoramic camera shutter times are matched.

Table 4-8. Tape and Fastrand Unit Assignments

	Tape Unit			
	I/O Unit Designator	FORTRAN Unit Number	Tape Description	FORTRAN Tape Assign Statement (With R-Option)
Input Tapes	A	1	JPL19, Planetary Ephemeris tape (Fastrand)	7/8R ASG A=$JPL19
	B	2	HOPE special trajectory FORMAT3 tape	7/8R ASG B=Tbbbbb
	C	3	Gimbal data tape	7/8R ASG C=Tccccc
	X	MTAPE = 27	Apollo Photo Evaluation Star Catalog	7/8R ASG X=00158*
Output Tape	D	4	APE Output Tape	7/8RS ASG D=TSAVE
APE PCF Tape	Z	29	APE program PCF tape 1st file...relocatable only 2nd file...symbolic only	7/8R ASG Z=00157** 00163

*Available in the TRW ancient tape library.

**TRW00157 is used for CSM mounted cameras, the panoramic camera, and the lunar sounder. TRW00163 is used for the IR scanner. These tapes are available in the TRW ancient tape library.

4.1.2.2 Input Trajectory Data Tape

The APE input vehicle ephemeris data tape must be in the HOPE special trajectory format 3 specified below in Tables 4-9 through 4-11.

Table 4-9. Identification Record for the Format 3 Trajectory and APE Output D-Tapes

Word	Type	APE Variable Name	Description	
1-2	DP	HPETME(1)	Year (mod. 1900)	
3-4	DP	HPETME(2)	Month	
5-6	DP	HPETME(3)	Day	Base Time
7-8	DP	HPETME(4)	Hour	
9-10	DP	HPETME(5)	Minute	
11-12	DP	HPETME(6)	Second	
13-14	DP	DUM3(1)	Minutes from launch to the base time	
15-16	DP	DUM3(2)	Right ascension of Greenwich, midnight day of launch (base time if GET = zero)	
17-18	DP	DUM3(3)	Right ascension of Greenwich, midnight of base day	
19-28	Hol.	HPEHOL(1) ...(10)	Ten word BCD title (60 alphanumeric characters) read in on the title card of HOPE run	
29	Hol. (A6)	HPEHOL(11)	BCD program indicator: "HOPEbb" or "APEbbb"	

Table 4-10. Data Records of Format 3 Trajectory Tape
(Units in e.r., minutes, and radian, except DUM82(44) = ω rad/sec.)

Identifier	Word	Type	APE Variable Name	Description
Time tag	1-2	DP	DUM82(1)	Time from base time, in minutes
Vector 1	3-8	DP	DUM82(2),(3), and (4)	Vehicle position vector, geocentric, MOF50
	9-14	DP	DUM82(5),(6), and (7)	Vehicle velocity vector, geocentric, MOF50
	15-20	DP	DUM82(8),(9), and (10)	Vehicle acceleration vector, geocentric, MOF50
Vector 2	21-26	DP	DUM82(11),(12), and (13)	Vehicle position vector, selenocentric, MOF50
	27-32	DP	DUM82(14),(15), and (16)	Vehicle velocity vector, selenocentric, MOF50
	33-38	DP	DUM82(17),(18), and (19)	Vehicle acceleration vector, selenocentric, MOF50
Vector 3	39-44	DP	DUM82(20),(21), and (22)	Vehicle position vector, selenographic
	45-50	DP	DUM82(23),(24), and (25)	Vehicle velocity vector, selenographic
	51-56	DP	DUM82(26),(27), and (28)	Vehicle acceleration vector, selenographic
Vector 4	57-74	DP	DUM82(29)...(37)	Vehicle P.V.A. vector, ECT(RTCC)
Sun Direction	75-80	DP	DUM82(38),(39), and (40)	Direction cosines of Sun, geocentric, MOF50
Sun Direction	81-86	DP	DUM82(41),(42), and (43)	Direction cosines of Sun, selenocentric, MOF50
ω	87-88	DP	DUM82(44)	IR scanning radiometer shaft rotation rate, ω in radian/sec only for the case of the nonstandard FORMAT3 trajectory tape; otherwise, zero
TV	89-138	DP	DUM82(45)...(69)	TV containing 0.0D+0

Table 4-10. Data Records of Format 3 Trajectory Tape (Continued)

Identifier	Word	Type	APE Variable Name	Description
Sun Direction	139-144	DP	DUM82(70),(71), and (72)	Direction cosines of Sun, selenographic
TV	145-146	DP	DUM82(73)	TV (not used)
	147-148	DP	DUM82(74)	Semi-major axis (a)
	149-150	DP	DUM82(75)	Eccentricity of orbit (e)
	151-152	DP	DUM82(76)	Inclination (i)
Vector 9	153-154	DP	DUM82(77)	Longitude of ascending node (Ω)
	155-156	DP	DUM82(78)	Argument of perifocus (ω)
	157-158	DP	DUM82(79)	Eccentric anomaly (E)
	159-160	DP	DUM82(80)	Mean anomaly (M)
	161-162	DP	DUM82(81)	Latitude (φ)
	163-164	DP	DUM82(82)	Longitude (λ)
	165-206	DP	COVMAT(1)...(21)	Selenographic covariance matrix in lower triangular form
TV	207	Real	EOREOF	TV (not used)

Table 4-11. Terminator Record of the Format 3 Trajectory Tape

Identifier	Word	Type	APE Variable Name	Description
TV	1-164	DP	DUM82(1)...(82)	TV (not used)
TV	165-206	DP	COVMAT(1)...(21)	TV (not used)
Terminator	207	Real	"EOR" if additional cases follow "EOF" if this was last case	

4.1.2.3 <u>Input Vehicle Attitude (Gimbal) Data Tape</u>

The vehicle attitude data required for APE computations can be input by tape in either of the formats defined in Tables 4-12 and 4-13. Regardless of which format is used, the tape contents must be free of all anomolous data.

<u>The Apollo Standard CSM Downlink Data Format</u>

This, a "non-FORTRAN" data tape presents the data in 516 word physical records. There are no control words. Each physical record presents two sets of gimbal angles and a single data record time. The first gimbal angle set corresponds to a time .84 seconds prior to record time while the second set corresponds to a time .16 seconds after record time. The record format is defined in Table 4-12.

<u>Apollo BMPROG Gimbal Angle Data Tape</u>

The BMPROG gimbal angle data tape presents chronologically ordered CSM gimbal angle sets. each with a unique time tag. Each physical record contains 20 such data sets along with three command words. The 83 word BMPROG data record format is shown in Table 4-13.

Table 4-12. Pre-Apollo 15 (Downlink) Gimbal Tape Format

TAPE BUFF Address or Data Word	Type	Variable Name	Unit	Description
1-41	Real	None	-	41 TV (not used)
42	Real	CDUX=TGO(I)	Degree	Outer gimbal angle at time, TGOTME(I)
43	Real	CDUY=TGI(I)	Degree	Inner gimbal angle at time, TGITME(I)
44	Real	CDUZ=TGM(I)	Degree	Middle gimbal angle at time, TGMTME(I)
[illegible]	Real	None	-	56 TV (not used)
101	Real	CDUT=TRUN(I)	Degree	Sextant trunnion angle
102	Real	CDUS=SHAFT(I)	Degree	Sextant shaft angle
103-155	Real	None	-	53 TV (not used)
156	Real	THOW	Second	Record time
157-173	Real	None	-	17 TV (not used)
174	Real	CDUX=TGO(J)	Degree	Outer gimbal angle at time, TGOTME(J)
175	Real	CDUY=TGI(J)	Degree	Inner gimbal angle at time, TGOTME(J)
176	Real	CDUZ=TGM(J)	Degree	Middle gimbal angle at time, TGOTME(J)
177-212	Real	None	-	36 TV (not used)
213	Real	None (old TRUNK))	-	One TV (it is not used, but it was CDUT)
214-516	Real	None	-	303 TV (not used)

Table 4-13. Post-Apollo 14 (BMPROG) Gimbal Tape Format

Data Word	Type	Variable Name	Unit	APE BUFF	Description
1	Real	Time #1	Second	BUFF(2)	Gimbal time #1
2	"	$CDUX_1$	Degree	BUFF(3)	Gimbal angle, TGO at time #1
3	"	$CDUY_1$	Degree	BUFF(4)	Gimbal angle, TGI at time #1
4	"	$CDUZ_1$	Degree	BUFF(5)	Gimbal angle, IGM at time #1
5	Real	Time #2	Second	BUFF(6)	Gimbal time #2
6	"	$CDUX_2$	Degree	BUFF(7)	Gimbal angle, TGO at time #2
7	"	$CDUY_2$	Degree	BUFF(8)	Gimbal angle, TGI at time #2
8	"	$CDUZ_2$	Degree	BUFF(9)	Gimbal angle, TGM at time #2
⋮					
77	"	Time #20	Second	BUFF(78)	Gimbal time #20
78	"	$CDUX_{20}$	Degree	BUFF(79)	Gimbal angle, TGO at time #20
79	"	$CDUY_{20}$	Degree	BUFF(80)	Gimbal angle, TGI at time #20
80	"	$CDUZ_{20}$	Degree	BUFF(81)	Gimbal angle, TGM at time #20

4.1.2.4 Apollo Photo Evaluation Star Catalog

For the special "stellar camera" application, the input on unit X of the special "Apollo Photo Evaluation" star catalog tape is required. This catalog, a special arrangement of specific data extracted from the SAO star catalog tape, resides in the TRW ancient tape library (Tape 00158). Each physical data record contains fifty (50) 7-word logical records. The data record format is described below in Table 4-14.

Table 4-14. Apollo Photo Evaluation Star Catalog Format

Data Word	Type	Variable Name	Unit	Description
1	Real	A(1,1)	(N.D.)	SAO star number
2	Real	A(2,1)	(N.D.)	Magnitude of brightness
3	Real	A(3,1)	Degrees	SAO right ascension in the mean of 1950.0
4	Real	A(4,1)	Degrees/Yr.	SAO right ascension (MOF50) proper motion
5	Real	A(5,1)	Degrees	SAO declination in the mean of 1950.0
6	Real	A(6,1)	Degrees/Yr.	SAO declination (MOF50) proper motion
7	Real	A(6,1)	N.D.	Boss star number
8-14	Real	A(i,2), where i= 1,...7		(the second set of the seven variables, the same as above)
15-21	Real	A(i,3), where i= 1,...7		(the third set of the seven variables, the same as above)
22-343	Real	A(i,j), where i= 1,...7; j=4,...19		(the 16 sets, from 4th to 19th, of the seven variables, the same as above)
344-350	Real	A(i,20), where i= 1,...7		(the 20th set of seven variables, the same as above)

4.1.2.5 APE PCF Tapes

The APE PCF tapes, TRW00157 and TRW00163, are located in the TRW an-ient tape library at TRW Systems Group, Houston Operations facility. The first file of these tapes contains all of the relocatable elements, while the second file contains all of the symbolic elements. TRW00157 is used for all CSM fixed-mounted cameras, the panoramic camera (with the alters defined in Appendix A.1), and the lunar sounder (with the alters defined in Appendix A.2). TRW00163 is used for IR scanner applications.

4.2 OUTPUT

For a general application, APE produces the standard on-line printouts and standard output D-tapes. The former are defined and described in Table 2-1, and the formats of the latter are described in Table 4-15. For a special application, APE produces various special output tapes. These are described in Tables 4-16 through 4-18.

The on-line printouts can be duplicated on the 4060 film by request. The additional three control cards, ∇PLT, ∇L FPR, and ∇N FPR, are required for the film plotting.

For the stellar camera case (ISHFTR = 3), the special on-line plots are produced to simulate the star patterns. In the following two subsections, tne tape outputs and the on-line outputs are described in detail.

4.2.1 Tape

For the general application, APE produces the standard output D-tape as specified in Tabel 4-15 if the input flag option, IPTOUT, is set to one (ITPOUT = 1).

For the special applications, APE produces the following special output tapes:

"IR Scanner Output Tape," Table 4-16
"Lunar Sounder Output Tape," Table 4-17
"Lunar Sounder Formatted Output Tape," Table 4-18

4.2.1.1 The Standard Output D-Tape

The general application of APE will produce the standard output D-tape if the input flag option, IPTOUT, is set to one (ITPOUT = 1). The standard

Table 4-15. Format of the Standard Output D-Tape

Data Word	Type	Variable Name	Unit	Description
1	Real	IGMT(1)	Year	Year (mod. 1900) — Base Time (GMT)
2	"	IGMT(2)	Month	Month
3	"	IGMT(3)	Day	Day
4	"	IGMT(4)	Hour	Hour
5	"	IGMT(5)	Minute	Minute
6	"	GMTSEC	Second	Second
7	Real	IDAY	Day	Day — Elapsed time from launch (as defined by card inputs)
8	"	IHR	Hour	Hour
9	"	IMIN	Minute	Minute
10	"	FSEC	Second	Second
11-13	Real	GDB(1)...(3)	Km	Vehicle state vector, X and $\dot{X}$, in selenocentric mean of 1950.0
14-16	"	GDB(4)...(6)	Km/sec	
17-19	Real	X(1)...(3)	Km	Vehicle state vector, X and $\dot{X}$, in selenographic
20-22	"	X(4)...(6)	Km/sec	
23	Real	XLO	Degree	Longitude of vehicle nadir point
24	"	XLA	Degree	Latitude of vehicle nadir point
25	"	XLOC	Degree	Longitude of camera axis intersect
26	"	XLAC	Degree	Latitude of camera axis intersect
27	Real	R	km	Vehicle radius
28	"	ALT	Km	Vehicle altitude
29	"	SFH	m/Km	Scale factor
30	"	VAZ	Degree	Azimuth of velocity vector
31	"	HDOT	Km/sec	Mean altitude rate
32	"	VTHETA	Km/sec	Horizontal velocity
33	"	AZM	Degree	Tilt azimuth
34	"	TILT	Degree	Tilt angle
35	Real	DUM18(12)	Degree	Sigma tilt azimuth
36	"	DUM18(10)	Degree	Sigma tilt angle
37	Real	SEA	Degree	Sun elevation at principal ground point
38	"	SAI	Degree	Sun azimuth at principal ground point
39	"	SSLN	Degree	Longitude of subsolar point
40	"	SSLT	Degree	Latitude of subsolar point
41	"	ALPHA	Degree	Alpha (see Table 2-1) angle
42	"	SWING	Degree	Swing (see Table 2-1) angle
43	"	EPS	Degree	Emission angle

Table 4-15. Format of the Standard Output D-Tape (Continued)

Data Word	Real	Variable Name	Unit	Description
44	Real	DUM18(1)	Degree	Sigma swing angle
45	Real	PHASE	Degree	Phase angle
46	Real	DAN	Degree	North deviation angle
47	Real	PHI	Degree	PHI
48	Real	DUM30(4)	Degree	X-tilt angle
49	Real	DUM18(16)	Degree	Sigma PHI
50	Real	DUM18(13)	Degree	Sigma X-tilt
51	Real	KAPPA	Degree	KAPPA
52	Real	DUM30(5)	Degree	Y-tilt
53	Real	DUM18(17)	Degree	Sigma KAPPA
54	Real	DUM18(14)]	Degree	Sigma Y-tilt
55	Real	OMEGA	Degree	OMEGA
56	Real	DUM30(6)	Degree	Heading
57	Real	DUM18(18)	Degree	Sigma OMEGA
58	Real	DUM18(15)	Degree	Sigma heading
59	Real	ALTIM(1)	Km	Vehicle (laser) altitude
60	Real	ALTIM(2)	Km	Laser slant range
61-63	Real	COPT(1),(2),(3)	N.D.	Selenographic direction cosines of camera axes
64	Real	C	Km	Magnitude of vector from camera to principal ground point
65-73	Real	DUM30(19)...(27)	N.D.	Elements of the transformation matrix, SG2CM
74-82	Real	DUM30(10)...(18)	N.D.	Elements of the transformation matrix, LH2CAM
83-90	Real	PFOOT(1,1)... (8,1)	Degree	Photograph footprint (latitude and longitude of four corners)
91	Real	IRA(1) = IRAHRS	Hour	Right ascension of stellar photo center
92	Real	IRA(2) = IRAMIN	Min	
93	Real	RASEC	Sec	
94	Real	IDEC(1)	Degree	Declination of stellar photo center
95	Real	IDEC(2)	Min	
96	Real	DECSEC	Sec	

Table 4-16. Format of the Special Output D-Tape for the IR Scanner

Each physical record consists of a chronologically ordered set of nine of the below logical records.

Data Word Number	Type	APE Variable Name	Unit	Description
(Where n = 0,1,2...,8)				
1+28*n	Real	AET	Millisecond	Actual elapsed time
2+28*n	Real	X(1)	Km	Vehicle state vector in selenographic
3+28*n	Real	X(2)	Km	
4+28*n	Real	X(3)	″	
5+28*n	Real	XLO		Longitude of nadir point
6+28*n	Real	XLA		Latitude of nadir point
7+28*n	Real	XLOC		Longitude of IR scanner axis intersect
8+28*n	Real	XLAC		Latitude of IR scanner axis intersect
9+28*n	Real	ALT	Km	Vehicle altitude
10+28*n	Real	VAZ	Degree	Azimuth of velocity vector
11+28*n	Real	HDOT	Km/sec	Mean altitude rate
12+28*n	Real	VTHETA	Km/sec	Horizontal velocity
13+28*n	Real	AZM	Degree	Tilt azimuth
14+28*n	Real	TILT	Degree	Tilt angle
15+28*n	Real	SEA	Degree	Sun elevation angle at principal ground point
16+28*n	Real	KAPPA	Degree	KAPPA (see Table 2-1)
17+28*n	Real	PHI	Degree	PHI (see Table 2-1)
13+28*n	Real	OMEGA	Degree	OMEGA (see Table 2-1)
(19, 20, or 21)+28*n	Real	COPT(1),(2),(3)	N.D.	Selenographic direction cosines
22+28*n	Real	LATTIR	Millisecond	Limb crossing (trailing) time
23+28*n	Real	LATLIR	Millisecond	Limb crossing (leading) time
24+28*n	Real	NU	Degree	Angular vehicle position
25+28*n	Real	DUM18(10)	Degree	Sigma tilt
26+28*n	Real	DUM18(16)	Degree	Sigma Phi
27+28*n	Real	DUM18(17)	Degree	Sigma Kappa
28+28*n	Real	DUM18(18)	Degree	Sigma Omega

Table 4-17. Lunar Sounder Special Unformatted Binary Output F-Tape

Data Word	Type	APE Variable Name	Unit	Description
1	Real	THR	Hour	
2	Real	TM	Minute	Time (GMT)
3	Real	SEC	Second	
4-9	Real	GDB(1),(2),(3),(4),(5),(6)	Km,Km/sec	Vehicle state vector, X and $\dot{X}$, in selenocentric, mean of 1950.0
10	Real	LONG	Degree	Longitude of nadir point
11	Real	LAT	Degree	Latitude of nadir point
12	Real	CDUX	Degree	Outer gimbal angle
13	Real	CDUY	Degree	Inner gimbal angle
14	Real	CDUZ	Degree	Middle gimbal angle

Table 4-18. Lurar Sounder Special Formatted Output E-Tape

This is an 800 bpi 9-track tape. The data for each APE computation point are written onto this tape with even parity as IBM EBCDIC words into data record pairs. The formats of the two data records of each pair are as follows:

- First Record

Data Word Description	Data Time From Launch			Vehicle Position (X,Y,Z) Mean of 1950 (Km)	Vehicle Velocity ($\dot{X},\dot{Y},\dot{Z}$) Mean of 1950 (Km/sec)	Vehicle Nadir Point	
	Hr	Min	Sec			Long (Deg)	Lat (Deg)
Format	F5.0	F4.0	F6.3	3F13.7	3F11.7	F8.3	F7.3

- Second Record

Data Word Description	Data Time From Launch			Vehicle Gimbal Angles (ϕ_X,ϕ_Y,ϕ_Z) Outer, Middle, and Inner, Respectively (Deg)
	Hr	Min	Sec	
Format	F5.0	F4.0	F6.3	3F8.3

output D-tape consists of three parts which are the identification record, the data records, and the termination record. The identification record is the first record of the tape and is in the same format as the identification record for the HOPE special trajectory format 3 tape defined in Table 4-9. The terminator record is the last record of the standard tape and is in the same format as the terminator record for the HOPE special trajectory format 3 tape defined in Table 4-11. The data record consists of 96 single precision words and is defined in Table 4-15.

4.2.1.2 The Special Output D-Tape for Panoramic Camera

The output D-tapes produced from panoramic camera APE applications, by setting ITPOUT = 1, are only slightly different in content and format from those produced from generalized APE applications (Section 4.2.1.1). The title and terminating records are, as for the generalized application, identical with their HOPE special trajectory format 3 counterparts. For the panoramic camera applications, the first 90 words of the data records are defined in Table 4-15 and are identical with their generalized application counterparts. The remaining words are defined below.

Data Words	Type	Variable Name
91-98	Real	PFOOT(1,1)...(8,1). Inner photograph footprint (latitude and longitude of four corners)

4.2.1.3 The Special Output D-Tape for IR Scanner

The identification record is the first record of the tape, and the format is of the same format as that for the HOPE special trajectory format 3, identification record, which has been defined in Table 4-9.

The terminator record is the last record of the special tape and is of the format defined in Table 4-11.

Each data record consists of nine logical records of 28 single-precision words each. The contents of each logical record are defined in Table 4-10.

4.2.1.4 The Special Output F- and E-Tape for Lunar Sounder

The special application of APE, with the alter decks of Appendix A.2 for subroutines APECOM and EVAL, produce two special lunar sounder output tapes, F-tape and E-tape.

The special tape, F-tape, is an unformatted binary tape defined in Table 4-17.

The special tape, E-tape, is a formatted output tape defined in Table 4-18.

4.2.2 Listing

In this section, various on-line output examples are presented both for the general applications and the special applications of APE. The following is a list of these examples.

Figure 4-2 Nominal On-Line Output, General Application of APE for the SIM-Bay Mapping Camera

Figure 4-3 Special On-Line Output, Special Application of APE for the Stellar Camera

Figure 4-4 Special On-Line Output, Special Application of APE for the IR Scanner

Figure 4-5 Special On-Line Output, Special Application of APE for the Lunar Sounder

Figure 4-6 Nominal On-Line Output, General Application of APE for the Panoramic Camera

Figure 4-7 On-Line Printout of the Namelist Input Variables

```
A17R62 BY T00097(HC21JK=SEPT05,73)#/B=A07911,C=T00293 FOR AADATE  120973  PAGE    16

                         APOLLO 17   OP.61/HC21JK/ APOLLO 17,      PAGE -   2152

                             YEAR   MONTH   DAY   HOUR  MINUTE  SECOND
                         GMT1972     12      15    20      2     7.671
                         CTE                  8    19     29     9.403
STATE VECTOR        X (KM)          Y (KM)          Z (KM)       XDOT (KM/S)    YDOT (KM/S)    ZDOT (KM/S)
 1950.0        1696.84 5541    200.6870008    -716.9017127    -.0081543     -1.5626198     -.9520790
SELENOGRAPHIC  -1500.0799398   836.3135532    -495.5605595    .7189670      1.9903533      .1932892

LONGITUDE OF NADIR POINT           150.8600190 DEG      LATITUDE OF NADIR POINT              -22.0475218 DEG
              150 DEG, 51 MIN, 36.0502625 SEC                               -22 DEG,  2 MIN, 5.0707866 SEC
LONG OF CAMERA AXIS INTERSECT      150.6428699 DEG      LATI OF CAMERA AXIS INTERSECT        -21.9594998 DEG
              150 DEG, 38 MIN, 34.3318176 SEC                               -21 DEG, 59 MIN, 22.1993065 SEC
SPACECRAFT RADIUS                 1852.9727951 KM       SPACECRAFT ALTITUDE                  114.8827987 KM
SCALE FACTOR                          .0004584 M/KM     AZIMUTH OF VELOCITY VECTOR           277.3389987 DEG
MEAN ALTITUDE RATE                   -.0018027 KM/SEC   HORIZONTAL VELOCITY                    1.6266896 KM/SEC
TILT AZIMUTH                       286.0376091 DEG      TILT ANGLE                             3.1677077 DEG
SIGMA TILT AZIMUTH                    .0036623 DEG      SIGMA TILT ANGLE                        .0001977 DEG
SUN ELEVATION AT PRIN GRND PNT      -2.6095638 DEG      SUN AZIMUTH AT PRINCIPAL GRND PNT    268.2471866 DEG
LONGITUDE OF SUBSOLAR POINT         57.5667799 DEG      LATITUDE OF SUBSOLAR POINT             -.6465941 DEG
              57 DEG, 34 MIN,         .3895283 SEC                                 0 DEG, 38 MIN, 47.7388000 SEC
ALPHA                               -3.2119190 DEG      SWING ANGLE                          273.0293902 DEG
EMISSION ANGLE                       3.3753280 DEG      SIGMA SWING ANGLE                       .0036623 DEG
PHASE ANGLE                         95.8219130 DEG      NORTH DEVIATION ANGLE                167.0149646 DEG
PHI                                  3.1619110 DEG      X-TILT                                  .1672206 DEG
SIGMA PHI                             .0001988 DEG      SIGMA X-TILT                            .0002011 DEG
KAPPA                             -166.9871273 DEG      Y-TILT                                -3.1613977 DEG
SIGMA KAPPA                           .0002000 DEG      SIGMA Y-TILT                            .0001988 DEG
OMEGA                                 .1672206 DEG      HEADING                              -76.9962567 DEG
SIGMA OMEGA                           .0002011 DEG      SIGMA HEADING                           .0002003 DEG
SPACECRAFT ALTITUDE (LASER)        115.9328040 KM       LASER SLANT RANGE                    114.1099997 KM


SELENOGRAPHIC DIRECTION COS S        X                  Y                  Z                MAGNITUDE (KM)
    OF CAMERA AXIS              .82916857          .90199967          .36894409             115.070027

         TRANSFORMATION MATRIX FROM                            TRANSFORMATION MATRIX FROM
          SELENOCENTRIC TO CAMERA                               LOCAL HORIZONTAL TO CAMERA

  .86119031-01  -.97363257+00  -.21129163+00         -.97287291+00   .22967091+00   .55190805-01
 -.40284568+00   .15989282+00  -.90119349+00         -.22516901+00  -.97431538+00  -.29185465-02
  .91120790+00   .16270769+00  -.37865389+00          .53074413-01  -.15257187-01   .99897392+00

                              PHOTOGRAPH FOOTPRINT
                              LATITUDE   LONGITUDE
                               -19.820    159.273
                               -25.379    152.983
                               -24.244    146.517
                               -18.199    148.159

                          DIRECTION TO STELLAR PHOTO CENTER

RIGHT ASCENSION      -1 HR, 5 MIN, 4.3 SEC            DECLINATION           59 DEG, 1 MIN, 38.8 SEC
```

Figure 4-2. Nominal On-Line Output, General Application of APE for the SIM-Bay Mapping Camera

```
AI7R62 BY T3D097(HC21JK=SEPT05,7318/B=A07911,C-(D3293 FOR DAUATE  120973  PAGE     17

                    APOLLO 17   ONI1I/HC21JK/ APOLLO 17,       PAGE -    2153

                         YEAR    MONTH    DAY    HOUR   MINUTE   SECOND
                      GMT1972      12      15     20       2     32.900
                      CTE                   8     14      29     39.632
STATE VECTOR       X (KM)          Y (KM)         Z (KM)        XDOT (KM/S)     YDOT (KM/S)      ZDOT (KM/S)
 1950.0         1696 2236496     161.2177250   -728.1301607    -.0911951       -1.5661380       -.9380116
SELENOGRAPHIC  -1981.5305983     872.6949992   -690.5193261     .7480539        1.9296865        .2007591

LONGITUDE OF NADIR POINT          199.4998035 DEG     LATITUDE OF NADIR POINT                  -21.8798920 DEG
              199 DEG, 29 MIN, 59.2927551 S                              -21 DEG, 52 MIN, 47.9313545 SEC
LONG OF CAMERA AXIS INTERSECT     199.3127651 D.      LATI OF CAMERA AXIS INTERSECT            -21.8405255 D.G
              199 DEG, 18 MIN, 45.9544373 SEC                            -21 DEG, 50 MIN, 54.6910869 SEC
SPACECRAFT RADIUS                1852.9272387 KM      SPACECRAFT ALTITUDE                      114.0372424 KM
SCALE FACTOR                        .0006591 M/KM     AZIMUTH OF VELOCITY VECTOR               277.8462509 DEG
MEAN ALTITUDE RATE                 -.0018085 KM/SEC   HORIZONTAL VELOCITY                        1.6267255 KM/SEC
TILT AZIMUTH                      280.1919060 DEG     TILT ANGLE                                 2.6672999 DEG
SIGMA TILT AZIMUTH                  .0043014 DEG      SIGMA TILT ANGLE                            .0001998 DEG
SUN ELEVATION AT PRIN GRND PNT    -1.3830233 DEG      SUN AZIMUTH AT PRINCIPAL GRND PNT        268.7489512 DEG
LONGITUDE OF SUBSOLAR POINT        57.5632293 DEG     LATITUDE OF SUBSOLAR POINT                 -.6465848 DEG
              57 DEG, 33 MIN, 47.6253605 SEC                               0 DEG, 38 MIN, 47.7051549 SEC
ALPHA                              -2.7863322 DEG     SWING ANGLE                              271.6197257 DEG
EMISSION ANGLE                      2.8937326 DEG     SIGMA SWING ANGLE                           .0043014 DEG
PHASE ANGL                         94.1694231 DEG     NORTH DEVIATION ANGLE                    171.3386586 DEG
PHI                                 2.6664084 DEG     X-TILT                                      .0707159 DEG
SIGMA PHI                           .0001999 DEG      SIGMA X-TILT                                .0002001 DEG
KAPPA                            -171.3261890 DEG     Y-TILT                                    -2.6669069 DEG
SIGMA KAPPA                         .0002000 DEG      SIGMA Y-TILT                                .0001999 DEG
OMEGA                               .0707154 DEG      HEADING                                  -81.3299863 DEG
SIGMA OMEG                          .0002001 DEG      SIGMA HEADING                               .0002002 DEG
SPACECRAFT ALTITUDE (LASER)       115.7115011 KM      LASER SLANT RANGE                        115.8369999 KM


SELENOGRAPHIC DIRECTION COSINES        X                Y                Z              MAGNITUDE (KM)
      OF CAMERA AXIS               .81929865        -.42944906        .37989896           114.970091

           TRANSFORMATION MATRIX FROM                               TRANSFORMATION MATRIX FROM
            SELENOCENTRIC TO CAMERA                                 LOCAL HORIZONTAL TO CAMERA

 .24109772-01  -.96113635+00  -.27501958+00           .98750129+00   .15058886+00   .46520775-01
-.40318567+00   .29   791+00  -.88243383+00          -.15080885+00  -.98856220+00  -.12342166-02
 .91480071+00   .13215483+00  -.38167374+00           .45802020-01  -.82345487-02   .99891660+00

                               PHOTOGRAPH FOOTPRINT
                               LATITUDE   LONGITUDE
                               -19.419     152.169
                               -25.084     151.945
                               -24.392     145.420
                               -18.282     146.566

                          DIRECTION TO STELLAR PHOTO CENTER

RIGHT ASCENSION        -1 HR, 37 MIN, 39.1 SEC          DECLINATION        56 DEG, 59 MIN, 19.7 SEC
```

Figure 4-2. Nominal On-Line Output, General Application of APE for the SIM-Bay Mapping Camera (continued)

```
MTAPE    =            +27,
MIZ      =          .0000000  00000000000+000,
SIGPHP   =     .1745329CE-01,
SIGTHS   =     .C0000000E+00,
SIGINT   =     .00000000E+00,
SIGTAU   =     .00000000E+00,
TAUTHE   =     .00000000E+00,
TDATA    =     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,
THETAS   =     .90000000E+02,
THETFS   =     .7*000000E+03,     .74000000E+02,     .10764670E+02,
 .70000000E+04,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,     .00000000E+00,
 .00000000E+00,     .00000000E+00,     .00000000E+00,
ISLT     =            +2,
PHIIRS   =     .00000000E+00,
STM      =          .000000000000000000D+000,
CTM      =          .000000000000000000D+000,
ISSEQ    =          +1395,
ISSEG    =          +2000,
BRILL    =     .00000000E+00,
$END

                    REV 29 MAP 4/73F          FRAME NUMBER = 1395                          YEAR MONTH DAY HOUR MINUTE SECOND
                    RT ASCENTION = -.603963291996830172+000  GMT  1972   12   13   2    35   51.198
                    DECLINATION  =  .973233698203375720+000  GET                    5  21    10   53.730
                                                          FRAME CORNERS
 -.160116L123572630?1+000   .110774197701976420+001                  -.2849501914985998147+00   .800682930240008192+000
 -.077256911994625O212+000   .7?035169?012975873+000                   -.10705937997490947561+0   .10653.431565767261+001

BRILLANCE HAS BEEN CHANGED TO 6 0
```

Figure 4-3. Special On-Line Output, Special Application of APE for the Stellar Camera

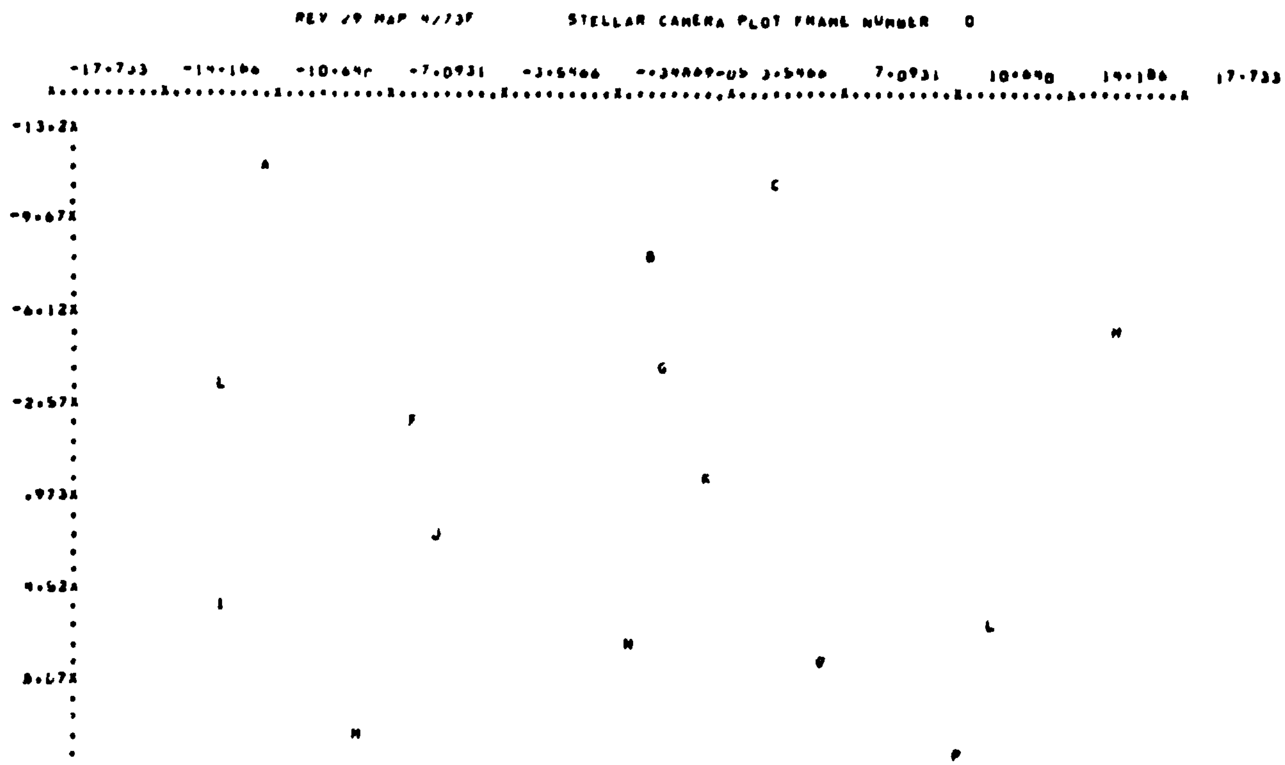


Figure 4-3. Special On-Line Output, Special Application of APE for the Stellar Camera (Continued)

STAR	Y DIAPOS	X DIAPOS	SAO NO.	BOSS NO.
A	-11.5461	-11.9277	18807.0	28304.0
B	-8.1351	-.0964	19541.0	30302.0
C	-11.3225	3.9770	19827.0	30877.0
E	-3.1346	-13.3800	32627.0	28531.0
F	-2.1116	-7.3015	33078.0	29393.0
G	-3.6681	.3820	33693.0	30440.0
H	-5.4829	14.5688	35147.0	32197.0
I	4.9866	-13.4540	32809.0	28865.0
J	2.2570	-6.7081	33185.0	29608.0
K	.3836	1.6122	33819.0	30627.0
L	5.8367	10.7066	34628.0	31586.0
M	9.8562	-9.1675	50456.0	29519.0
N	6.3308	-.7985	33665.0	30391.0
O	7.0850	5.2570	34143.0	31046.0
P	11.1490	9.4782	52055.0	31426.0

Figure 4-3. Special On-Line Output, Special Application of APE for the Stellar C..mera (Continued)

```
EXAMPLE OF IR SCANNER BY DATA AND ALTER DECK OF MC21JK*OCT23DATE  291073  PAGE    40

                                                   IFRAME =  869
                                  YEAR    MONTH    DAY    HOUR   MINUTE  SECOND
                              GMT 1972     12      16       6      8     .519+002
                              CTE                  16       0      0     .000
STATE VECTOR       X             Y                  Z              X DOT             Y DOT           Z DOT
 1950.0        .1947467+004  -.7532830+003   -.8719469+003   -.4667860+002    -.8579315+002   -.3185846+001
SELENOGRAPHIC -.6950599+003   .1648174+004   -.4725514+003    .8261257+002     .4315858+002    .2935966+002

                                                   IFRAME =  1093
                                  YEAR    MONTH    DAY    HOUR   MINUTE  SECOND
                              GMT 1972     12      16       6     26     .713+001
                              CTE                  16       0      0     .000
STATE VECTOR       X             Y                  Z              X DOT             Y DOT           Z DOT
 1950.0        .1888358+003  -.1745562+004   -.5821024+003   -.8899277+002    -.2115672+002    .3992753+002
SELENOGRAPHIC  .8146567+003   .1653904+004    .1497321+003    .7960999+002    -.4252668+002    .3771224+002

                                                   IFRAME =  1094
                                  YEAR    MONTH    DAY    HOUR   MINUTE  SECOND
                              GMT 1972     12      16       6     26     .887+001
                              CTE                  16       0      0     .000
STATE VECTOR       X             Y                  Z              X DOT             Y DOT           Z DOT
 1950.0        .1866979+003  -.1746025+004   -.5812624+003   -.8700315+002    -.2103955+002    .3996559+002
SELENOGRAPHIC  .8165480+003   .1652039+004    .1506322+003    .7995332+002    -.4263640+002    .3770127+002

                                                   IFRAME =  1095
                                  YEAR    MONTH    DAY    HOUR   MINUTE  SECOND
                              GMT 1972     12      16       6     26     .100+002
                              CTE                  16       0      0     .000
STATE VECTOR       X             Y                  Z              X DOT             Y DOT           Z DOT
 1950.0        .1845594+003  -.1746487+004   -.5809222+003   -.8901350+002    -.2092236+002    .3950355+002
SELENOGRAPHIC  .8184397+003   .1651774+004    .1518326+003    .7939668+002    -.4274615+002    .3769829+002
```

Figure 4-4. Special On-Line Output, Special Application of APE for the IR Scanner

```
                  LUNAR SOUNDER TEST CASE FOR AA5300C/APE3 (COPY OF JB/SE0263)DATE  121073  PAGE    52
                                YEAR    MONTH    DAY    HOUR   MINUTE  SECOND
                             GMT1972     12      16      20      13    19.756
                             CTE                 16       0       0      .000
STATE VECTOR        X (KM)          Y (KM)          Z (KM)       XDOT (KM/S)      YDOT (KM/S)      ZDOT (KM/S)
 1950.0          832.5501822   -1451.0830427    -784.9188892   -1.3009218       -.9267939        .3300999
SELENOGRAPHIC*******************************************************************************************

LONGITUDE OF NADIR POINT           77.7354717 DEG      LATITUDE OF NADIR POINT                -4.1990017 DEG
                  GIMBALS       .000         .000         .000

                             APOLLO 17    REV 74 MAP 4/73F              PAGE -      52

                                YEAR    MONTH    DAY    HOUR   MINUTE  SECOND
                             GMT1972     12      16      20      13    40.000
                             CTE                 16       0       0      .000
STATE VECTOR        X (KM)          Y (KM)          Z (KM)       XDOT (KM/S)      YDOT (KM/S)      ZDOT (KM/S)
 1950.0          799.4009947   -1474.1884646    -776.3645964   -1.3169745       -.8979648        .3454575
SELENOGRAPHIC    420.9541371    1793.5921156    -119.2501309    1.4702786       -.3078521        .6383083

LONGITUDE OF NADIR POINT           76.5494614 DEG      LATITUDE OF NADIR POINT                -3.6998748 DEG
                  GIMBALS       193.020      393.619      .681

                             APOLLO 17    REV 74 MAP 4/73F              PAGE -      53

                                YEAR    MONTH    DAY    HOUR   MINUTE  SECOND
                             GMT1972     12      16      20      14     5.421
                             CTE                 16       0       0      .000
STATE VECTOR        X (KM)          Y (KM)          Z (KM)       XDOT (KM/S)      YDOT (KM/S)      ZDOT (KM/S)
 1950.0          765.8309395   -1496.5741846    -767.9173831   -1.3323803       -.8607287        .3606860
SELENOGRAPHIC    466.2227735    1785.2626859    -103.1223982    1.4614929       -.3431791        .6374998

LONGITUDE OF NADIR POINT           75.3640399 DEG      LATITUDE OF NADIR POINT                -3.1986632 DEG
                  GIMBALS       193.167      392.315      .687

                             APOLLO 17    REV 74 MAP 4/73F              PAGE -      54

                                YEAR    MONTH    DAY    HOUR   MINUTE  SECOND
                             GMT1972     12      16      20      14    30.796
                             CTE                 16       0       0      .000
STATE VECTOR        X (KM)          Y (KM)          Z (KM)       XDOT (KM/S)      YDOT (KM/S)      ZDOT (KM/S)
 1950.0          731.9804547   -1518.1999099    -758.0933667   -1.3471116       -.8390493        .3756610
SELENOGRAPHIC    503.2393140    1776.0937807     -86.9534472    1.4518806       -.3783090        .6393632

LONGITUDE OF NADIR POINT           74.1805799 DEG      LATITUDE OF NADIR POINT                -2.6968354 DEG
                  GIMBALS       193.305      390.869      .516

                             APOLLO 17    REV 74 MAP 4/73F              PAGE -      55

                                YEAR    MONTH    DAY    HOUR   MINUTE  SECOND
                             GMT1972     12      16      20      14    56.003
                             CTE                 16       0       0      .000
STATE VECTOR        X (KM)          Y (KM)          Z (KM)       XDOT (KM/S)      YDOT (KM/S)      ZDOT (KM/S)
 1950.0          697.5890588   -1539.0790002    -748.3870113   -1.3611775       -.8089779        .3904062
SELENOGRAPHIC    590.8111820    1766.8381460     -70.7338075    1.4415864       -.4132631        .6909199

LONGITUDE OF NADIR POINT           72.9976786 DEG      LATITUDE OF NADIR POINT                -2.1934822 DEG
                  GIMBALS       193.437      339.494      .297
```

Figure 4-5. Special On-Line Output, Special Application of APE for the Lunar Sounder

```
AA5300C/APE3(MCZ1JK=SEPT20,1973) APOLLO 17,REV 15,PANORAMIC DATE  200973  PAGE    52

                         APOLLO 17   REV 15 PAN 4/73F              PAGE - F 2129

                             YEAR   MONTH    DAY    HOUR  MINUTE  SECOND
                         GMT1972     12       11     23     26     32.851
                         CTE                   4     17     52     34.690
STATE VECTOR         X (KM)         Y (KM)          Z (KM)        XDOT (KM/S)      YDOT (KM/S)      ZDOT (KM/S)
 1950.0          -517.0561075   -1730.4922130   -462.3834862   -1.4342572       .2956494         .7012620
SELENOGRAPHIC    -271.4829497    1829.3409390    235.7064763    1.5235352       .1556815         .5136237

LONGITUDE OF NADIR POINT           98.4913567 DEG      LATITUDE OF NADIR POINT                  7.2632967 DEG
               98 DEG, 26 MIN, 20.8039722 SEC                               7 DEG, 15 MIN, 47.0679895 SEC
LONG OF CAMERA AXIS INTERSECT      97.5957079 DEG      LATI OF CAMERA AXIS INTERSECT            7.5318992 DEG
               97 DEG, 35 MIN, 44.5984161 SEC                               7 DEG, 31 MIN, 54.6391153 SEC
SPACECRAFT RADIUS                1844.3360228 KM       SPACECRAFT ALTITUDE                    128.2960265 KM
SCALE FACTOR                         .0000000 M/KM     AZIMUTH OF VELOCITY VECTOR             288.7158990 DEG
MEAN ALTITUDE RATE                  -.0041596 KM/SEC   HORIZONTAL VELOCITY                      1.6152698 KM/SEC
TILT AZIMUTH                      287.8107229 DEG      TILT ANGLE                              11.9268159 DEG
SIGMA TILT AZIMUTH                   .0009677 DEG      SIGMA TILT ANGLE                          .0002000 DEG
SUN ELEVATION AT PRIN GRND PNT     79.2379923 DEG      SUN AZIMUTH AT PRINCIPAL GRND PNT      140.1063919 DEG
LONGITUDE OF SUBSOLAR POINT       104.4746798 DEG      LATITUDE OF SUBSOLAR POINT               -.7596639 DEG
              104 DEG, 28 MIN, 28.6292980 SEC                               0 DEG, 45 MIN, 34.7900391 SEC
ALPHA                              -6.9864058 DEG      SWING ANGLE                            269.6603986 DEG
EMISSION ANGLE                     12.8073631 DEG      SIGMA SWING ANGLE                         .0009677 DEG
PHASE ANGLE                         6.8232544 DEG      NORTH DEVIATION ANGLE                  161.9085892 DEG
PHI                                11.9245090 DEG      X-TILT                                   -.2359106 DEG
SIGMA PHI                            .0002000 DEG      SIGMA X-TILT                              .0002000 DEG
KAPPA                            -161.0723019 DEG      Y-TILT                                 -11.9244010 DEG
SIGMA KAPPA                          .0002000 DEG      SIGMA Y-TILT                              .0002000 DEG
OMEGA                               -.2359106 DEG      HEADING                                -71.0224821 DEG
SIGMA OMEGA                          .0002000 DEG      SIGMA HEADING                             .0002099 DEG
SPACECRAFT ALTITUDE (LASER)          .0000000 KM       LASER SLANT RANGE                         .0000000 KM


SELENOGRAPHIC DIRECTION COSINES        X                 Y                  Z                MAGNITUDE (KM)
     OF CAMERA AXIS                .33827427         -.93906877         -.06099471              129.291267


            TRANSFORMATION MATRIX FROM                                 TRANSFORMATION MATRIX FROM
             SELENOCENTRIC TO CAMERA                                   LOCAL HORIZONTAL TO CAMERA

  -.92512159+00  -.46846998-01   .37676956+00                -.92529017+00   .31817970+00   .20662089+00
  -.36967528+00   .33735103+00  -.86575657+00                -.32937198+00  -.94592063+00   .91179098-02
  -.86545517-01  -.94021253+00  -.32940887+00                 .19675708+00  -.63212910-01   .97041237+00

                                         PHOTOGRAPH FOOTPRINT
                    LATITUDE   LONGITUDE                    LATITUDE   LONGITUDE
                     13.252      99.992                      10.211      98.997
                      1.481      95.913                       4.577      97.001
                      1.455      94.943                       4.719      96.184
                     13.851      99.230                      10.612      98.185

DUMB2
   .16857518499999905+001    .51775035705437634 9+002   -.31083665956427287 04+002   -.99033680008970439 7+001
  -.90021215654040862 7+002   .97276242018802234 3-002    .10968605021298198 9+001    .22052028920194269 201+003
   .74017091147872359 2+003   .19565503840437663 3-003   -.81375397432109100 0+001   -.27191186168076031 1+000
  -.71764741364114901 2+001  -.13408325846983358 7+001    .23436940356441691 0+002    .65930680051816932 11+002
   .22181437295914726 7+003   .73941681937600756 6+003    .19542783773650615 9+003   -.40875037872879571 0+001
```

Figure 4-6. Nominal On-Line Output, General Application of ?PE for the Panoramic Camera

```
AA53DOC/APE3(MC2(JK-SEPT20,1973; APOLLO 17,REV 15,PANORAMIC DATE  200973  PAGE   37

$INPUT1
DELTCL  =     .00000000E+00,
DETUT   =          .667615799999999999D+000,
IFLAG   =                +3,
IGMFLE  =                +0,
IINNER  =                +0,             +0,             +0,             +0,
IMID    =                +0,             +0,             +0,             +0,
IOUTER  =                +0,             +0,             +0,             +0,
IPROBE  =                +1,
ISHFTR  =                +4,
ISTPRT  =                +1,
ISVFLE  =                +0,
ITELE   =                +0,
ITNOW   =                +0,
ITPOUT  =                +1,
LCHYR   =             +1972,
LCHMTH  =               +12,
LCHDAY  =                +7,
LCHHR   =                +5,
LCHMIN  =               +33,
LCHSEC  =     .00000000E+00,
OPTANG  =     .12000000E+02,
OPTDEL  =     .00000000E+00,
RFSMAT  =          -.927136200000000000D+000,
 .367325600000000000D+000,         -.740962999999999999D-001,
-.207642500000000000D+000,         -.338999500000000000D+000,
 .917565899999999999D+000,          .311934200000000000D+000,
 .866112699999999999D+000,          .390571100000000000D+000,
STRTHR  =              +113,
STRTMN  =               +51,
STRTSC  =     .10000000E+02,
STPHR   =              +114,
STPMN   =               +20,
STPSC   =     .45000000E+02,
SXLAMB  =          .000000000000000000D+000,
TAU     =     .12500000E+02,
RHO     =          .000000000000000000D+000,
INT     =                +0,
ISHFT   =                +0,             +0,             +0,             +0,
ITRUN   =                +0,             +0,             +0,             +0,
SIGBET  =     .20000000E-03,
SIGBPR  =     .00000000E+00,
SIGDEL  =     .00000000E+00,
SIGGAM  =     .00000000E+00,
SIGGPR  =     .00000000E+00,
SIGR1   =     .00000000E+00,
SIGR2   =     .00000000E+00,
SIGR3   =     .00000000E+00,
SIGRHO  =     .00000000E+00,
SIGTHE  =     .20000000E-03,
SIGTPR  =     .00000000E+00,
RMOON   =          .570238360882000000D+007,
THEMR   =     .90000000E+02,
TMAX    =     .10000000E+01,
SIGPSI  =     .20000000E-03,
GM      =     .49025800E+04,
RE      =          .637814919999999999D+004,
APL     =     .00000000E+00,     .00000000E+00,
```

Figure 4-7. On-Line Printout of the Namelist Input Variab' s

```
AAS3DOC/APE3(HC2(JK=SEPT20,1973) APOLLO 17,REV 15,PANORAMIC DATE  200973  PAGE   38

AP@      =     .00000000E+00,    .00000000E+00,
D        =     .00000000E+00,    .00000000E+00,
PHIM     =     .00000000E+00,
THTM     =     .00000000E+00,
PHIC     =     .90000000E+02,
THTC     =     .00000000E+00,
PHILR    =     .11000000E+03,
PHIMR    =     .11000000E+03,
THELR    =     .90000000E+02,
PHIFLR   =     .20000000E+02,
FL       =     .00000000E+00,
PHIFHR   =     .20000000E+02,
THEFLR   =     .90000000E+02,
THEFHR   =     .90000000E+02,
FRINC    =     .12000000E+00,
THTMF    =     .50000000E+01,
THTMS    =     .20000000E+02,
THTLF    =     .38000000E+02,
THTLS    =     .99000000E+02,
FCLLO    =     .60000000E-01,
FCLMI    =     .60000000E+00,
F@       =     .00000000E+00,
G        =     .21700000E-01,
ALPC     =     .95710300E+02,
DELC     =    -.52667560E+02,
NOP      =     .00000000E+00,
MODE     =     .20000000E+01,
ORBIT    =     .30000000E+02,
RES      =     .10000000E+01,
IRU      =     .10000000E+01,
NOF      =     .10000000E+01,
MI       =     .00000000E+00,
FRAME1   =     .10000000E+01,
EPOCH    =     .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,
TIME1    =     .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,
TIME2    =     .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,
AU       =           .14959790000000000D+009,
MISSNO   =     .17000000E+02,
TAPE     =     .90000000E+01,
PTAPE    =     .00000000E+00,
NPTS     =     .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
  .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
```

Figure 4-7. On-Line Printout of the Namelist Input Variables (Continued)

```
AAS300C/APE3(MC21JK=SEPT20,1973) APOLLO 17,REV 15,PANORAMIC DATE  200973  PAGE   39
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+0
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
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.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
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.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
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.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
.00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
```

Figure 4-7. On-Line Printout of the Namelist Input Variables (Continued)

```
AAS300C/APE3(HC21JK=SEPT20,1973) APOLLO 17,REV 15,PANORAMIC DATE  200973  PAGE   40
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,
CAMA    =   .00000000E+00,  .00000000E+00,  .00000000E+00,
CONTRL  =   .30000000E+02,  .10000000E+01,  .10000000E+01,
 .10000000E+01,  .00000000E+00,
CC      =   .00000000E+00,  .00000000E+00,  .90000000E+02,
 .00000000E+00,
CCC     =   .11000000E+03,  .11000000E+03,  .90000000E+02,
 .90000000E+02,  .20000000E+02,  .20000000E+02,  .90000000E+02,
 .90000000E+02,  .12000000E+00,
CAM     =   .50000000E+01,  .20000000E+02,  .38000000E+02,
 .44000000E+02,  .60000000E+00,  .80000000E-01,  .21700000E-01,
CAMO    =   .95710300E+02, -.52467560E+02,
FLCA    =   .00000000E+00,
P44     =   .00000000E+00,
MAN     =   .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,
MAN1    =   .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,
MAN2    =   .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,
MAN3    =   .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,
MAN4    =   .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,
MAN5    =   .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,
TGT     =   .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,  .00000000E+00,
 .00000000E+00,  .00000000E+00,  .00000000E+00,
TGT1    =   .00000000E+00,  .00000000E+00,
TGT2    =   .00000000E+00,  .00000000E+00,
TGT3    =   .00000000E+00,  .00000000E+00
TGT4    =   .00000000E+00,  .00000000E+00
```

Figure 4-7. On-Line Printout of the Namelist Input Variables (Continued)

```
AAS3UOC/APE3(HC21JK*SEPT20,1973) APOLLO 17,REV 15,PANORAMIC DATE  200973  PAGE   41
TGTS     =      .00000000E+00,     .00000000E+00,
BTRTH    =      .20000000E-01,
BTRTL    =      .10000000E+00,
CFL      =      .60967999E+00,
C1       =               .12000000000000000000D+002,
C2       =               .90000000000000000000D+001,
DUMB2    =               .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,          .00000000000000000000D+000,
 .00000000000000000000D+000,
G1       =               .00000000000000000000D+000,
IPRS     =                    +2,
KINTPC   =                    +0,
KOPAN    =                    +0,
P1       =               .00000000000000000000D+000,
P2       =               .00000000000000000000D+000,
P12      =               .00000000000000000000D+000,
PDELT    =      .00000000E+00,
PHIMAP   =      .37750000E+02,
PSTGET   =      .00000000E+00,     .00000000E+00,     .00000000E+00,
```

Figure 4-7. On-Line Printout of the Namelist Input Variables (Continued)

```
AAS:DOC/APE3(HC21JK=SEPT20,1973) APOLLO 17,REV 15,PANORAMIC DATE  200973  PAGE    42

MTAPE   =          +27,
R12     =              .000000000000000000+000,
SIGPHP  =      .17453290E-01,
SIGTHS  =      .00000000E+00,
SIGINT  =      .00000000E+00,
SIGTAU  =      .00000000E+00,
TAUTME  =      .00000000E+00,
TDATA   =      .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,
THETAS  =      .90000000E+02,
THETFS  =      .10766667E+02,    .10800000E+03,    .10766670E+02,
 .70000000E+02,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,    .00000000E+00,
 .00000000E+00,    .00000000E+00,    .00000000E+00,
ISLT    =           +0,
PHIIRS  =      .00000000E+00,
STH     =              .000000000000000000+000,
CTH     =              .000000000000000000+000,
ISSEQI  =           +0,
ISSEQF  =           +0,
BRILL   =      .00000000E+00,
SEND

HOPE TIME
    .719999999999999999+002    .120000000000000000+002    .110000000000000000+002
    .230000000000000000+002    .240000000000000000+002    .125728547573089600-006
HPEHOL =APOLLO 17 REV 15                                            APE

DELTME =   .71640000+04     SECELP =   .4098700. 06
TSTART =  .716416666666666666+004     TSTOP =  .719375000000000000+004

CUMB2
   .000000000000000000         .817909498013 22 91+002   -.310990084069492429+002   -.942071337328500991+001
  -.932113731947175942-002     .847277411921754496-002    .101137920327488008-001    .157727219329517738-003
   .747663801911196038-004     .225030950173308219-003   -.583518351478687655-001   -.279307611989505102+000
  -.825805667422235502-001    -.138095096097096345-001    .109011536352106492-002    .623942815964889526-002
   .159013060018861755-003     .746909438702871711-003    .224803599918477289-003   -.646510853795550390-001
   .283598955382524108+000     .293656841895063337-001    .141057027726982956-001    .267078031798967281-002
   .497166497836579155-002     .175908014987397627-003   -.772235513697058255-003   -.800262648418745857-004

EOREOF =

DUMB2
   .525118249999998454+000     .817856227674425986+002   -.310944561875426980+002   -.941537182110516807+001
  -.923313239082077479-002     .886495555230599508-002    .102296102913815528-001    .177434643098738303-003
   .745933126251594447-003     .216054870255283743-003   -.655806297301298460-001   -.273632268435004762+000
  -.792815450817525412-001    -.137208293812920434-001    .198190049843528131-002    .635512708512933795-002
   .178720559185874266-003     .745178847836432482-003    .215827566599374415-003   -.671967093313077408-001
   .284899582120812727+000     .319650469486858737-001    .141929469653695836l-001    .226309449592450980-002
```

Figure 4-7. On-Line Printout of the Namelist Input Variables (Continued)

APPENDIX A

APPENDIX A

APE ALTER DECKS

Alter decks to Tape TRW00157 are required for the generation of support data for the panoramic camera and the lunar sounder. Sections A.1 and A.2 list the associated alters for each application.

A.1 APE ALTERS FOR THE PANORAMIC CAMERA

The required alters for the generation of panoramic camera support data are listed below.

```
'  ASG Z=A04089
'SW ASG D=ASAVE
' ASG A=$JPL19
' XQT CUR
  TRW Z
 ERS
  IN Z
 IN Z
  TRI Z
' FOR,* EVAL,EVAL
-73,73
      DIMENSION TAPMAP(98)
-537,542
      TAPMAP(91)= PFOOT(1,2)
      TAPMAP(92)= PFOOT(2,2)
      TAPMAP(93)= PFOOT(3,2)
      TAPMAP(94)= PFOOT(4,2)
      TAPMAP(95)= PFOOT(5,2)
      TAPMAP(96)= PFOOT(6,2)
      TAPMAP(97)= PFOOT(7,2)
      TAPMAP(98)= PFOOT(8,2)
```

A.2 APE ALTERS FOR THE LUNAR SOUNDER

The required alters for the generation of lunar sounder support data are listed below.

```
@ ASG Z=T00097
@SKEW ASG E=ASAVE
@SW ASG F=ASAVE1
@ ASG A=$JPL19
@ XGT CUR
  TRW Z
 ERS
  IN Z
 IN Z
  TRI Z
@N FOR,* APECOM,APECOM
-33
      COMMON /GIMBAL/ GIMBAL(3)
-377
      GIMBAL(1)= GIMB(1)
      GIMBAL(2)= GIMB(2)
      GIMBAL(3)= GIMB(3)
-385,386
-406,407
-413,416
      GIMBAL(1)= 0.0
      GIMBAL(2)= 0.0
      GIMBAL(3)= 0.0
      LONG= DATAN2(PSG(2),PSG(1))/DTOR
      LAT= DATAN(PSG(3)/DSQRT(PSG(1)**2+PSG(2)**2))/DTOR
      DYEAR= YEAR
      IF (MONTH.GT.6) DYEAR= DYEAR+1.0D0
      UJD1= 2433282.423357D0+ 365.242199D0*(DYEAR-1950.0D0)
      CALL ROTAT2(JD1950,UJD1,15,DETUT,DUM82(11),DUM28(11),2)
      CALL ROTAT2(JD1950,UJD1,15,DETUT,DUM82(14),DUM28(14),2)
      DUM28(20)= DUM82(20)* 1.0D10
      DUM28(21)= DUM82(21)* 1.0D10
      DUM28(22)= DUM82(22)* 1.0D10
      DUM28(23)= DUM82(23)* 1.0D10
      DUM28(24)= DUM82(24)* 1.0D10
      DUM28(25)= DUM82(25)* 1.0D10
-542,547
-1416,1419
      ENDFILE 7
      ENDFILE 8
      REWIND 7
```

```
      REWIND 8
'N FOR,* EVAL,EVAL
-72
      DIMENSION BUF1(8)
      COMMON /GIMBAL/ GIMBAL(3)
-97,98
-101,102
-106,106
-119,120
-122,264
-267,267
 1025 FORMAT(1H0,30X6HAPOLLO1XI2,3X4A6.5X7HPAGE - ,A1,1X,I4)
-285,491
      WRITE (6,2043) GIMBAL
 2043 FORMAT (1H ,20X, 7HGIMBALS, 3F11.3)
      DO 10 K= 1,6
      BUF1(K)= GDB(K)
   10 CONTINUE
      BUF1(7)= LONG
      BUF1(8)= LAT
      NHR= GNTME/3600.0D0
      THR= NHR
      MIN= (GNTME-THR*3600.0D0)/60.0D0
      TM= MIN
      SEC= (GNTME-THR*3600.0D0-TM*60.0D0)
      WRITE (8)       THR,TM,SEC,BUF1,GIMBAL
      WRITE (7,100) THR,TM,SEC,BUF1
      WRITE (7,101) THR,TM,SEC,GIMBAL
      RETURN
  100 FORMAT (F5.0,F4.0,F6.3,3F13.7,3F11.7,F8.3,F7.3)
  101 FORMAT (F5.0,F4.0,F6.3,3F8.3)
' XQT T1
```

REFERENCES

1. "Apollo Photograph Evaluation Program, Program Version 3 Documentation," MSC/TRW Task A-221 (TRW 5522.8-70), R. C. Thomas, 4 August 1969.

2. "APE Trajectory Data Pre-Processor (HOPGEN, HOPE, HPEINT, MAPDEX, LATPH, and IREX Programs)," TRW IOC IJK-74-2532.3-01, I. J. Kim, 18 January 1974.

3. "HOPE User's Manual," TRW Note No. 74-FMT-931, J. K. Daly, 25 January 1974.